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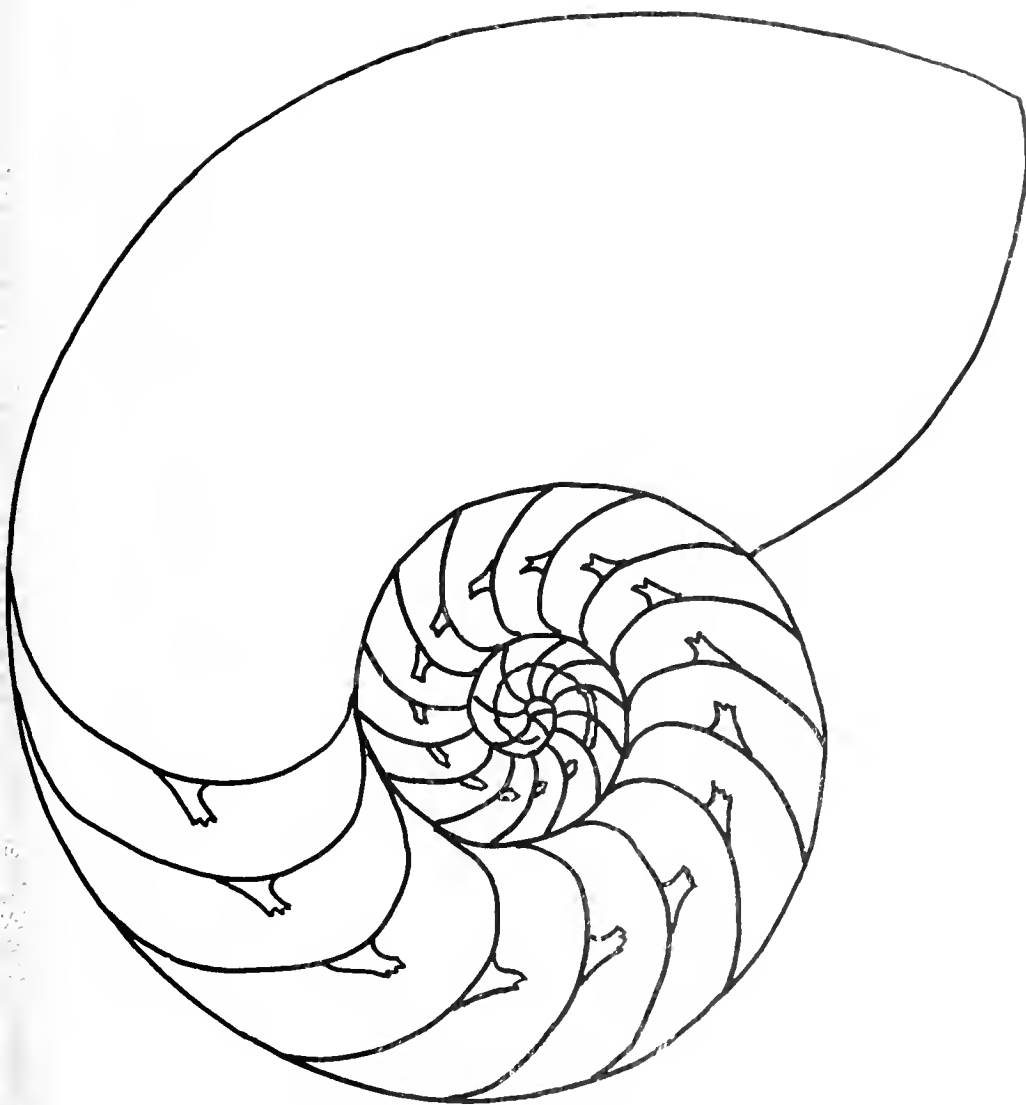
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## PUBLICATIONS RECEIVED

- Brooks, Stanley Truman (1902-1960). Bibliography by R. L. Johnson in *Occ. Papers Mollusks*, vol. 4, no. 59, pp. 266-268 (1981).
- Clarke, Arthur H. 1981. The Tribe Alasmidontini (Unionidae: Anodontinae), Part 1: *Pegias*, *Alasmidonta*, and *Arceidens*. *Smithsonian Contributions to Zoology*, no. 326, pp. iii + 1-191, 32 figs. Ecologic and taxonomic study with illustrations of shell, soft parts, glochidia, descriptions, distributional maps, synonymies, and simple anatomical test for sex determination. *Alasmidonta robusta* n. sp., extinct mussel from Charlotte, NC (not *Unio robusta* Sowerby, 1840).
- Habe, T. and Iwao Taki. 1981. A Catalogue of Molluscs of Wakayama Prefecture, the Province of Kii. 1. Bivalvia, Scaphopoda and Cephalopoda. *Publ. Seto Marine Biol. Lab., Special Series*, vol. 7, no. 1, pp. xx + 304, 13 pls. (One in color). Based on Kuroda's Manuscript. Eleven new species of Japanese Bivalvia are described. Synonymies very complete. 51 cephalopods treated by I. Taki (pp. 234-264).
- Johnson, Richard L. 1981. Recent and Fossil Unionacea and Mutelacea (Freshwater Bivalves) of the Caribbean Islands. *Occasional Papers on Mollusks*, vol. 4, no. 60, pp. 269-288. \$1.60 from Dept. Mollusks, Museum Comparative Zoology, Cambridge, MA 02138.
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- Rehder, Harald A. 1981. *The Audubon Society Field Guide to North American Seashells*. 894 pp., 705 color pls. An excellent pocket guide of the common shells, with especially good photographs by James H. Carmichael, Jr. Gives descriptions, habitats, range and both popular and Latin names, but unfortunately omits all authors and dates.
- Sharabati, Doreen. 1981. *Saudi Arabian Seashells*. 119 pp. VNU Books International. A popular account with numerous beautiful photographs, many of living mollusks.
- Thais. 1981. Publicaciones Diversas de la Sociedad Panameña de Malacología. No. 1 (La Fauna Malacológica Panameña), 28 pp.; No. 2 (Lista Preliminar de Referencias Bibliográficas Sobre la Fauna Malacológica Panameña), 59 pp. Both by Miguel C. Avilés E. Annual subscription Balboa 10.00 (U.S. \$10.00), Soc. Panameña de Malacología, Estafeta Universitaria, Panama, Rep. of Panama.

## RECENT DEATHS

- Grab, Robert McKay, former President of the Naples Shell Club, born New York City on April 19, 1904, graduate University of Michigan in 1926, died in North Carolina September 1981.
- Lyman, Frank, long-time shell dealer, editor of "Shell Notes" (1942-51), born in Lantana, Florida, June 10, 1895, died Oct. 11, 1981, in Ferandina Beach, Florida.
- Sexauer, Howard T. 1981-82 President of the Sanibel Captiva Shell Club, well-known poet, former resident of Montpelier, Vermont, died at age 82 in Florida on Dec. 1, 1981.
- Zeigler, Rowland Franklin, born June 1, 1915, in Greelyville, SC, formerly chief of obstetrics and gynecology at McLeod Hospital in Florence, SC, author (with Porreca) of "Olive Shells of the World" and articles in medical journals, died at age 66, on Sept. 21, 1981, in Durham, NC. His widow, Edna Jo continues his interests in olive shell.

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A NEW SPECIES OF *HIPPOPUS* (BIVALVIA: TRIDACNIDAE)**Joseph Rosewater**Department of Invertebrate Zoology  
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## ABSTRACT

*Hippopus porcellanus* n. sp. is described from Sibutu Island, Sulu Archipelago, Philippines, bringing the known members of the genus *Hippopus* to 3, including *H. hippopus* (Linné, 1758), Recent, Indo-Pacific, and *H. gunteri* Mansfield, 1937, Fossil, Lower Miocene of Florida.

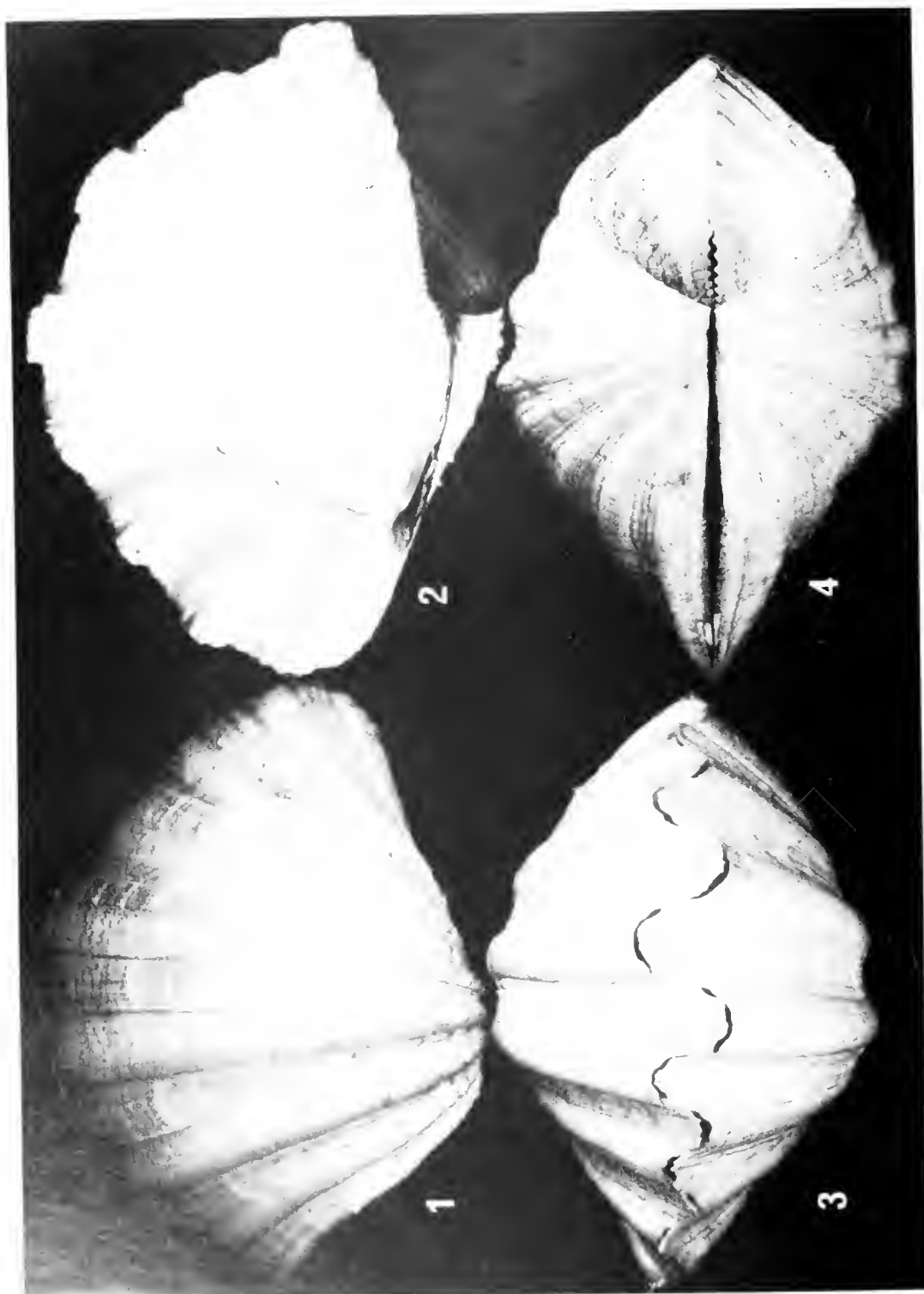
For several years shell dealers have received large numbers of a rather distinctive giant clam belonging to the genus *Hippopus* which they refer to as the "China Clam", and which they consider to be distinct from the "Horse's Hoof" or "Bear Paw", *Hippopus hippopus* (Linné, 1758). It is much thinner and smoother than the usually elaborately sculptured *H. hippopus*, and lacks most of the characteristic strawberry color of the latter. When I reviewed the classification of Tridacnidae this phenotype was believed to intergrade completely with *H. hippopus* (Rosewater, 1965, p. 361). Recent examination of nearly two dozen specimens of the "China Clam" and comparison with *H. hippopus* persuades me that they are separate species.

*Hippopus porcellanus* new species  
(Figs. 1-4)

**Description:** Shell reaching 216 mm (about 8 1/2 inches) in length, semicircular in outline and globose in shape; usually only moderately inflated; with valves closed byssal orifice is very narrowly gaping. Valves not excessively heavy, markedly translucent, colored occasionally with weak strawberry blotches arranged concentrically or scattered; color of interior porcellaneous, of exterior grayish white. Surface of valves remarkably clean, except for scattered coralline algae and debris. Primary radial sculpture consisting of 13 or 14 low rib-like folds distributed over surface of valve, extending on to ventral slope where they become obsolete. Secondary radial sculpture consisting of low riblets which are nearly obsolete on primary folds

but are more prominent in their interstices. Riblets varying somewhat in width, usually lacking spines or evidencing only microscopic concentric imbrications. A few low tubular spines present on primary fold bordering ventral slope and occasionally on ventral portions of other primary folds; folds usually smooth dorsally. Concentric sculpture consisting of microscopic, wavy, imbricate lines of growth. Dorsal margin undulate, with series of 8-9 rounded to squarish, medially projecting, interdigitating processes representing extremities of rib interstices. Hinge line usually longer than half the length of valve. One oblong cardinal tooth in each valve; 2 elongate posterior laterals in right and a single moderately sharp one in the left valve. Ligament secondarily prosodetic. Umbos directed postero-medially. Edge of byssal orifice with a series of 8-12 light-yellow, rather poorly developed plicae which remain fairly constant in size or become only slightly larger posteriorly. Ventral slope moderately concave. Hinge plate suffused with orange. Pallial line entire, moderately narrow. Muscle scars central, medium sized; the posterior adductor scar round in both valves, the posterior pedal retractor scar is smaller and elongate, the two extending over portions of two fold interstices in each valve. Area within pallial line, excluding muscle scars, dull; pallial line, muscle scars and areas to edge of shell shiny. Prodissoconch unknown.

The anatomy and life history of this species are unknown. Following my studies (Rosewater, 1965) several persons have achieved success in studying the spawning and development of *Hip-*



FIGS. 1-4. *Hippopus porcellanus* new species. Holotype ANSP 246690, from Sibutu Id., Philippines. 1, external view right valve; 2, internal view right valve; 3, dorsal view; 4, ventral view (for measurements see under Type).

*popus hippopus* (Jameson, 1976; Gwyther and Munro, 1981).

**Measurements (mm):** Tridacnidae are indiscriminately inequivalved, and the figures given under "length" and "height" are always the maximum measurement. "Width" is the greatest distance through opposed valves.

Locality (Philippines)	Zamboanga	Sibutu Id.	Masbate Id.	Sulu Sea
No. Specimens	10	5	1	6
Range of Lengths	87-138	75-157	216	93-214
Range of Heights	60-105	53-115	167	74-150
Range of Widths	46-78	35-101	141	48-126
Range of Weights, Left Valve (grams)	27-142	11-221	479	38-399
Average Width/Length	.60	.60	.66	.58

**Types:** Holotype ANSP (The Academy of Natural Sciences of Philadelphia) 246600, 157 mm length, 113 mm height; 3 paratypes ANSP 354770, 155 mm length, 115 mm height, 101 mm length, 81 mm height, and 75 mm length, 53 mm height; 1 paratype USNM (National Museum of Natural History, Washington, D.C.) 807720, 133 mm length, 98 mm height.

**Type locality:** Sibutu Island, Tawi Tawi Group, Sulu Archipelago, Philippines (4°46'N; 119°29'E), du Pont-Academy Expedition, 1958.

**Other Material Examined:** ANSP 209699 Zamboanga, Mindanao Island, Philippines, ex. A. B. Bronson, 1956 (10 specimens, see Measurements); ANSP 228977, Masbate Island, Philippines, du Pont-Academy Expedition, 1958 (1 specimen, see Measurements); USNM, "Sulu Sea", ex. A. D'Attilio and John Root (6 specimens, see Measurements).

**Distribution:** Philippines, mostly known from the Sulu Archipelago; 1 specimen from Masbate Island, central Philippines.

**Etymology:** "porcellanus", an adjectival name referring to the porcelain-like appearance of the shell of this species.

**Remarks:** Shells of this new species are consistently smoother, more semicircular in outline, proportionately lighter in weight and thinner than *H. hippopus* (see figs. 1-4). When viewed apart from the latter they present a rather ro-

tund appearance although measurements show they are no more obese, but, in fact, are often less wide. Compared with *H. hippopus*, *H. porcellanus* has a very narrow byssal orifice, with the plicae less well developed and lighter in color (fig. 4). The single posterior lateral tooth of the left valve is moderately sharp in *H. porcellanus* while in *H. hippopus* it is blunt.

The only other large bivalve species with which *H. porcellanus* is likely to be confused is *Tridacna derasa* (Röding, 1798). Specimens of *T. derasa*, of the same length as *H. porcellanus* (200 mm+), are smooth, may be similarly semicircular in outline and exhibit similar obesity. It is quite likely that living *T. derasa* has a considerably more colorful mantle, that of *H. hippopus*, at any rate, being rather sombre olive. The shell of *T. derasa* is even smoother than that of *H. porcellanus*, lacking in development of tubular spines and having low primary and secondary folds, although sometimes developing strong, continuous, undulate concentric ridges (Rosewater, 1965, pl. 281, fig. 1). Shells of *T. derasa* lack the orange and yellow coloration present in *Hippopus* in the areas of hinge and byssal orifice. Byssal plicae number 6-7, are low and elongate to nearly obsolete in *T. derasa* while in *H. porcellanus* they are shorter and number from 8-12. The posterior adductor muscle/posterior pedal retractor scar complex is comparatively larger in *T. derasa* and its umbos tend to be less distinctly convoluted than in *H. porcellanus*, although size for size the former tends to have a heavier shell.

I originally thought that *H. porcellanus* differed from *H. hippopus* subspecifically rather than specifically. As subspecies the two would normally have more or less discreet geographic ranges. While it appears that *H. porcellanus* lives mostly in the southern Philippines, more precisely the southern Sulu Sea, a specimen has been reported from Masbate Id. in the central Philippines. Furthermore, *H. hippopus* is distributed in the same area besides having a more extensive range in the western Pacific. Since the ranges of the two species seem not to be in any real way mutually exclusive, the subspecific status seems doubtful, and they are here considered to be separate species within the

genus *Hippopus*. It is quite obvious that the known geographic range of *H. porcellaneus* is considerably more restricted than that of *H. hippopus* (see Rosewater, 1965, pl. 272).

#### ACKNOWLEDGMENTS

Special thanks are expressed to those who assisted in gathering information and donating specimens: Anthony D'Attilio, John Root, Robert W. Morrison, R. T. Abbott, and Betty and Robert Lipe. I am grateful to R. Robertson, ANSP, for loaning specimens with accurate locality data. R. D. Turner, and K. J. Boss, Museum of Comparative Zoology, Harvard

University, and H. A. Rehder, and R. S. Houbick, USNM, offered helpful criticism.

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## OCCURRENCE OF THE ASIATIC CLAM *CORBICULA FLUMINEA* IN THE RARITAN RIVER, NEW JERSEY<sup>1</sup>

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#### ABSTRACT

*The mid-Atlantic range of the Asiatic clam, Corbicula fluminea (Müller, 1774) is extended to the Raritan River in central New Jersey. A successfully breeding population was found in the nontidal region near a water supply intake. These clams have also colonized far upstream into the South Branch of the Raritan but not the North Branch. No reason for this difference is known. Living specimens were found downstream in the tidal portion of the river which is freshwater but polluted. There was no evidence of reproduction in this region of the river.*

Since it was first observed in this country in the Columbia River, Washington (Dundee and Dundee, 1958) the Asiatic clam, *Corbicula fluminea* (Müller, 1774) (alias *manilensis* Philippi) has spread rapidly into many river systems across the United States (Sinclair, 1971). Extension of its range to the mid-Atlantic region was documented by Diaz (1974) in the James River,

Virginia, and by Fuller and Powell (1973) in the Delaware River between Philadelphia, Pennsylvania and Trenton, New Jersey. Diaz estimated the year of introduction in the James River to be 1968 and Fuller and Powell concluded that *Corbicula* was present in the Delaware River since at least 1971 or 1970. Crumb (1977) later reported it in the Delaware River between Trenton and Burlington in September 1971.

On March 26, 1981 many empty shells and a few living *Corbicula* were collected from a tidal (but freshwater) region of the Raritan River

<sup>1</sup>This study was supported by the Center for Coastal and Environmental Studies, Rutgers University. Assistance of Joy Bergelson in preparation of the manuscript is acknowledged.



near New Brunswick, New Jersey (Sta. 1, Fig. 1). Collections of macrobenthos taken from this same region in September 1980 did not contain any specimens of *Corbicula*. The largest shell collected in March 1981 was 25 mm in length and was estimated to be between 3 and 4 years of age at the time of death. It was concluded that the year of invasion was not later than 1978 and that the invasion site had to have been upstream from this point of initial discovery.

During July and August 1981 the occurrence and range of *Corbicula* in the Raritan River was studied. Sampling extended upstream from Sta. 1 (tidal but freshwater) into the North and South Branches of the Raritan River (Fig. 1).

At Sta. 1 many empty shells were again found. Many live specimens, however, were also collected from current-swept bottoms covered by gravel and small pebbles. The living clams fell into two size classes; largest specimen was 25 mm in length and had a grossly distorted shell growth that appeared to commence from a shell length of 20 mm. The smallest specimen was 15 mm in length and appeared normal.

The greatest population density and evidence of reproduction were found at Sta. 2 which is in the vicinity of the Elizabethtown Water Company's intake on the Raritan River which is non-tidal at this point. Largest living clams ranged from 15 to 17 mm in length and a first year class ranged from 2 to 6 mm in length. No *Corbicula* were found in the Millstone River (Sta. 3) immediately above its confluence with the Raritan River. The substrate in this portion of the Millstone River was soft muck and, therefore, was not a preferred habitat for these clams.

Very few living *Corbicula* were taken at Stations 4 and 5, and these ranged from 7 to 10 mm in length. Many empty shells were found at Sta. 4. Even though a suitable type substrate existed at Stations 6, 7 and 8 only one specimen of *Corbicula* (10 mm) was found at Sta. 6. None was found at Stations 7 or 8, nor was there evidence of dead *Corbicula* shells anywhere in the North Branch of the Raritan River. On the other hand, there were significant populations in the South Branch. Specimens ranged from 2.5 to 10 mm in length at Stations 9, 10 and 11. No dead

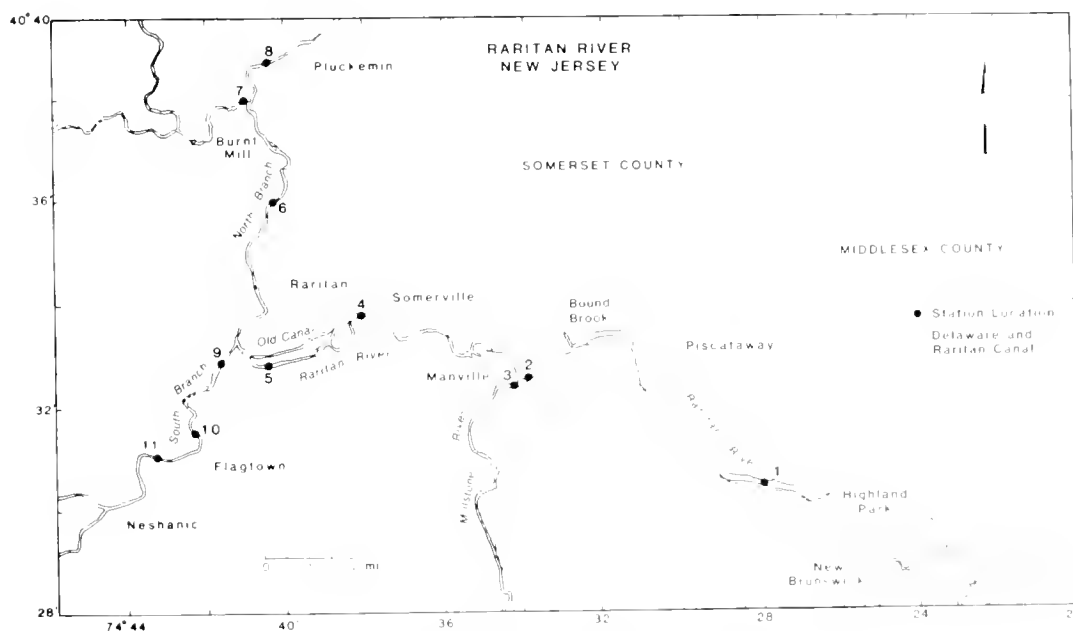


FIG. 1. Sample sites on the Raritan River, New Jersey. Sampling for *Corbicula* took place between July 23 and August 26, 1981.

specimens or empty shells were found in those locations.

It seems that the Asiatic clam has established itself in the tidal and nontidal, freshwater (even polluted) regions of the Raritan River. The population center (initial colonization?) is in the nontidal waters of the main stem in the vicinity of the intake of the Elizabethtown Water Company. Furthermore, this foreign species has successfully colonized the South Branch of the Raritan River but for some reason has not as yet moved very far into the North Branch of the Raritan River. This discovery extends the northern range of *Corbicula* in the mid-Atlantic region.

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## REDISCOVERY OF A PORTION OF THE ISELY UNIONID COLLECTIONS

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During a recent renovation of the Invertebrate Range at Stovall Museum of Science and History (University of Oklahoma), a collection of unionids was found carefully wrapped in old newspapers and stored away. Part of these were labeled as collected by F. B. Isely in Oklahoma between 1908 and 1912. The remaining unionids were also from Isely's collections. Upon inquiry with several malacologists, it appears that this is the largest extant portion of Isely's collections. These are part of the specimens collected by Isely for his study of the clams of Eastern Oklahoma, which appeared in 1925.

After rearrangement of the above specimens and merging of several other collections, a series of unlabeled unionids were found. These differed from all the other specimens, however, in that they had small, circular, numbered, copper tags wired to the shells. On further examination it was determined that these were a portion of the specimens used by Isely in his classical migration study (Isely 1914). They were also collected in Oklahoma.

The importance of these specimens is impor-

tant for several reasons. They were used by Isely and therefore are now voucher specimens for his works. Their presence also allows some insight into the taxonomy of his time or at least Isely's interpretation of it. Secondly, the specimens have a historical importance in that some of the streams Isely collected have now been altered so as to deplete the original unionid fauna. Finally, some of these specimens represent the only collections from various streams in Oklahoma.

Isely's specimens plus others donated to Stovall Museum form a nucleus for a growing collection of Oklahoma unionids. The Stovall collection combined with that located at OU's Biological Station on Lake Texoma (Texas-Oklahoma border) represents perhaps the major collections of Oklahoma unionids.

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## NAPOLEON'S EGYPTIAN CAMPAIGN (1798-1801) AND THE SAVIGNY COLLECTION OF SHELLS

**Philippe Bouchet and Francoise Danrigal**

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### ABSTRACT

*During the Napoleonic campaign to Egypt a collection of Red Sea, Mediterranean and continental mollusks was brought together by Savigny who published upon them in 1817 as folio engravings. These served as type-figures for a number of species described by 19th century malacologists, including Audouin, Ehrenberg, Deshayes, Philippi, Hupé, Landrin, Jonas, Issel, Morlet, Vaillant, P. Fischer, Tapparone-Canefri, von Martens, Weinkauff, Monterosato, Jousseaume, H. Fischer and finally Pallary. A checklist and illustrations of 86 of these original types from the Savigny collection, now in the Paris Museum, are presented, supplemented by reproductions of the unpublished color vellums of opisthobranchs and cephalopods.*

Jules César Savigny was born at Provins, France, on April 5, 1777. In 1793, in the middle of the Revolution, the Convention transformed the Royal Gardens into a "Museum d'Histoire naturelle". Savigny was then 16 years old and was sent to Paris to study at the "Ecole de santé" and the Museum. His professors were Lamarck, Cuvier, Daubenton; they noted the young student's assiduity and also took note that he was always wearing the same Nankin costume.

Lamarck was then writing the "Nouvelle Encyclopédie" and assigned Savigny his first work, the drafting of the part on the sorrel plant. This paper showed the wealth of his knowledge and soon he was named professor of botany at the "Ecole Centrale" in Rouen. Cuvier advised him to wear a wig to look older and more serious! But Savigny was never to go to Rouen. Napoleon Bonaparte was already preparing the Egyptian Campaign.

Bonaparte not only wanted to conquer the country but also make it a model of French culture. He added to the expedition troops a "Commission des sciences et des arts", consisting of scholars, painters, architects and others. Bonaparte asked his friend Cuvier to name the naturalists who would join the expedition. Savigny and Geoffroy Saint Hilaire were selected for the zoological part. Savigny was then 21 years old; he had been trained as a botanist, but Cuvier's opinion was that "he would become a zoologist when he would decide to".

### The Expedition

After the Battle of Campoformio in 1797, Bonaparte realized that he could not invade England, so he decided to make war on Egypt. In 1798, 38,000 men gathered at Toulon on 335 ships; among them were the members of the "Commission des Sciences et des Arts". On Floreal 30th, year VI, (i.e. May 19th, 1798) Geoffroy Saint Hilaire and Savigny left Toulon. They were to reach Alexandria 41 days later. Savigny was placed in the 4th class of the Commission, with a very low salary, but thanks to Geoffroy Saint Hilaire, he was soon admitted to the first class.

The Nile was flooding and the expeditionary forces were directed to Cairo which they entered on July 23 after the Battle of the Pyramids. During this time the Commission settled in Rosetta for a month. Savigny and Geoffroy Saint Hilaire stayed for several weeks in the islands of Lake Menzale; in September they visited Salahied and Damiette. They worked all during the autumn in the delta and left Damiette for Cairo in December. Geoffroy Saint Hilaire was exhausted, but Savigny was in very good condition. A current joke of the time in Cairo was to call scholars, the donkeys, then used as "taxis", because the members of the Commission were always travelling on donkeys.

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Between August 1 and 2, Nelson defeated the French Navy in Aboukir and cut all contacts with France. In Cairo, Bonaparte organized the country under his rule and founded the "Institut d'Egypte". He then prepared the expedition to Syria 13,000 infantrymen and the cavalry left in the beginning of February, 1799. After several victorious battles, Bonaparte was finally stopped at Saint Jean d'Arce, where 4,000 were killed. On June 14 the army was back in Cairo, Savigny was the only naturalist to follow the troops.

In August, Bonaparte turned over the command to Kleber and returned to Paris, where the "Directoire" was weakened. The members of the "Commission" were sent to Suez at the end of 1799. Savigny was very excited by the wealth and beauty of the Red sea fauna. But Kleber had to face the Turks and the British and the scholars were sent back to Cairo. Kleber was murdered shortly after he won the Battle of Heliopolis; France was then finally defeated at Canope in 1801.

The journey of the 45 members of the "Commission" back to France was rather unfortunate. On April 6, 1801, they left Cairo for Alexandria. On their arrival they were quarantined by the French general, Menou. They were transferred to a brig, and waited 21 days for permission to leave the bay. The British troops stopped them, took them to Abukir, then back to Alexandria. Menou had surrendered on terms stipulating that the collections gathered by the "Commission" in Egypt should be given to the British. The scholars rebelled and threatened to destroy the collections. Finally, on September 26, 1801, they were allowed to go back to France with their collections.

### The Original Plates

Savigny returned to Paris in February, 1802. He did a great amount of work on the material he took back with him and published various papers and memoirs between 1801 and 1810. Among them were the study of 1,200 insects and his famous "Histoire naturelle et mythologique de l'Égypte" (1805). In 1817, he published 125 plates for the atlas of the "Expedition d'Égypte" in "grand-aigle" size (71.5 × 52 cm); most of them were reprinted by Panckoucke in reduced size (68.5 × 52 cm). These engraved plates were made from the original colored vellum drawings preserved in this Museum's library. They have been reproduced very accurately, with a wealth of detail by the best artists of the time.

Because the "Commission" judged that they were too difficult to reproduce in color, only black and white copies were printed.

Savigny suffered progressively failing eyesight, approaching blindness after 1815, for which reason he never published any text to accompany the plates. But Cuvier found that this iconography was unique and Audouin was chosen to write an explanatory part. Audouin was a professor of entomology at the Museum, and was not prepared for this work. But he was the son-in-law of Brongniart, a member of the "Institut", director of the Sèvres manufacture, and a friend of the powerful Cuvier.

There is considerable difficulty in determining the exact dates of publication of the "Explication sommaire des planches", of which two editions were printed.

The first edition bears on the title page "publié par les ordres de sa majesté l'Empereur Napoléon Le Grand" and is dated 1809 on the cover page, but was evidently published much later (Laissus, 1973); the Mollusca are treated in tome 1, part 4, and begin with a copy of a letter dated Nov. 1, 1825! The register of the letters and declarations of the "Commission d'Egypte", kept in the Manuscript Department of the National Library, Paris, shows that the Natural History section belongs to the third issue of reports. On April 13, 1826 the last manuscript by Audouin concerning shells was sent to the "Imprimerie Royale", but we could not determine whether the first edition, third issue, was actually printed before the end of 1826. However it seems wise to assume that Sherborn (1897:287) was right and that this part "may be safely regarded as dated 1826."

Almost simultaneously a second edition, "dédiée au roi", was being printed by Panckoucke. This bears 1827 on the title page but it appears also that this date is a fake. Pallary accepted this date (1827) in a bibliography, but mentioned 1829 in the text (Pallary 1926). In fact the earliest date we can ascertain is July 19, 1828 (Bibliographie de la France, 1828).

The text was published while Savigny was still alive. When he became aware of the contents, he became very irritated and sent a letter to the Academy of Sciences. Later on, L. Pfeiffer pronounced similarly severe judgement, and reproached Audouin with the fact that he had taken all the benefit of Savigny's work. P. Fischer and Pallary had the same opinion. In the checklist, we have given references to both editions of Audouin's text because the first one is apparently very rare in libraries.

Savigny's work, despite its unfinished condition, was to interest naturalists for a long time. The very short explanations by Audouin were later completed, first by Issel (1869), then by Pallary (1926). But many other authors referred to Savigny, among them, Jonas (1846), Pfeiffer (1846), Vaillant (1865), P. Fischer (1865, 1870, 1871), von Martens (1866), Tapparone-Carnefri (1875), Jousseau (1888). Many of the specimens depicted by Savigny have therefore become the types of new species, which are enumerated below.

The Collection

From Egypt, Savigny brought back a rich collection of birds, fishes, mammals, insects and shells. Included were also mollusks in alcohol, given by Savigny to Cuvier in 1802; later on these were said to be deposited in the Gallery of Anatomy but we have been unable to trace them.

In 1853, the manuscripts, notes and collections of Savigny were offered to the town of Versailles. Curation was entrusted to the "Société des sciences naturelles et médicales de Seine et Oise". Deshayes once planned to publish a report on the Mollusca collection but never did (Landrin, 1865). In 1864, the Society realized its inability to curate the material properly and asked for help from the Museum. Valenciennes and Gratiolet were contacted, but the Society and the Museum lacked the sum of 2,500 francs to fund the naturalist who intended to work at Versailles. The collection then sank into oblivion. In 1919, the council of the "Société des Sciences naturelles" was disbanded because of World War I. The librarian of the Versailles library took this opportunity to transfer the collection in a very rough fashion to a cellar in order to gain some space.

In 1926, when Pallary wrote his "Explication des Planches", the vellums and collections of Savigny were considered to be lost. In April 1927, he visited his friend the bryozoologist, Canu, in Versailles and realized that some shells in the cellar of the municipal library matched exactly some depicted on Savigny's plates. Between August and September, he carefully studied the shells which were finally to join the national collections in 1930, together with the 5 volumes of vellums.

Pallary (1931, 1932, 1934) produced a very detailed history of the expedition and the collections together with a biography of Savigny. He evidently had planned to publish a report on the collection after he had rediscovered it, but only a

small part was published (1932); this concerned only the shells not depicted in the plates.

We are therefore producing here the latest chapter of this two centuries-old story with the realization of the nomenclatorial importance of this material.

Acknowledgements

We are grateful to the librarians who helped us during this work and to A. Foubert for Figures 1-51, Mrs. Guillaumin, Centre de Microscopie du C.N.R.S. for Figures 52-84 and P. Lafaité for the colorslides of the vellums, Figures 93-101. We wish to thank Mr. Richard E. Petit of South Myrtle Beach, South Carolina, for making possible the publication of the color plate.

Checklist of the names based partly or entirely on Savigny's plates.

It has been our intention to simply list the material on which a name is based, when the original description refers to the 1817 plates. Lectotype designation is the affair of the malacologist actually engaged in a process of revision of a group and should not be done for the mere sake of it, as is too often the case in such checklists.

We are aware of the fact that, strictly, only the very specimen depicted on Savigny's plate should be considered the type of later authors. It is, indeed, possible to recognize the type when it is a large and distinct shell, but it is not so when dealing with the many microgastropods, of which Savigny appears to have been the earliest collector in the Indo-Pacific.

*acgyptiaca* Ehrenberg, 1831 (*Succinea*) Fig. 61  
Savigny 1817: pl. 2, fig. 24  
Ehrenberg 1831: (no page number). Signature E.  
Name based on an unknown number of animals from Daniette and Savigny's figure. One shell in coll. Savigny. Ehrenberg collection in the Berlin Museum may contain specimens.

*acgyptiaca* Chenu, 1845 (*Tridacna*)  
Savigny 1817: pl. 10, fig. 1-2  
Chenu 1845: 2, pl. 7, fig. 1-2  
Name based on Savigny's plate and a number of subfossil shells from the Suez area. Judging from the illustrations, however, Chenu's shells have nothing to do with Savigny's, and are typical *Tridacna maxima* (Roding).

*affinis* Issel, 1869 (*Chiton*) Fig. 51  
Savigny 1817: pl. 3, fig. 8  
Issel 1869: 234  
Name based on Savigny's figure and seven specimens from the Gulf of Suez, now in MGD (Genoa, Italy). One specimen in coll. Savigny. See also *savignyi* Pulsby 1892.

*arabensis* Issel, 1869 (*Turbo*) Fig. 25  
Savigny 1817: pl. 5, fig. 28

Issel 1869: 220

Name based on Savigny's figure and a subfossil shell which could not be traced in MGD. Five shells in coll. Savigny.

*audouini* Jonas, 1846 (*Fasciolaria*)

Fig. 42

Savigny 1817: pl. 4, fig. 17

Jonas 1846a: 63

Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.

*audouini* Jousseaume, in Lamy, 1918 (*Pristis*)

Fig. 86

Savigny 1817: pl. 8, fig. 11

Lamy 1918: 30

Name based on Savigny's figure and two specimens from Suez, now in MNHN. No Savigny material left.

*bacillum* Issel, 1869 (*Cerithium*)

Fig. 77

Savigny 1817: pl. 4, fig. 28

Issel 1869: 340

Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.

*bertholleti* Issel, 1869 (*Rissoina*)

Fig. 38

Savigny 1817: pl. 4, fig. 2

Issel 1869: 208

Name based on Savigny's figure, named by Audouin 'Rissoa de Berthollett'. Two shells in coll. Savigny.

*bourquignati* Landrin, 1865 (*Unio*)

Fig. 4

Savigny 1817: pl. 2, fig. 3

Landrin 1865: 5, fig. 1-3

Name based on Savigny's figure and specimens collected by Savigny in Damiette (Landrin actually saw the collection). Three syntypes in coll. Savigny.

*brongnartii* Audouin, 1826 (*Tricolia*)

Fig. 26

Savigny 1817: pl. 5, fig. 23

Audouin 1826: 41; 1828: 181

Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.

*caillaudi* von Martens, 1866 (*Spatha*)

Fig. 1

Savigny 1817: pl. 7, fig. 1

von Martens 1866: 9

Name based on Savigny's figure and specimens in the collections of Caillaud, Mousson, Leiden Museum and British Museum. Two bivalve specimens and one valve in coll. Savigny.

*callasa* P. Fischer, 1871 (*Gena*)

Fig. 32

Savigny 1817: pl. 5, fig. 10

Fischer 1871: 218

Name based on Savigny's figure and specimens collected at Suez by Gaudry, which could not be traced. Two shells in coll. Savigny; the small one (3.2 mm) is here depicted. The larger one (5.8 mm) is chipped and smaller than the natural size shell depicted fig. 10.5 in Savigny.

*caerata* Pallary, 1926 (*Risella isseli* var.)

Savigny 1817: pl. 5, fig. 34

Pallary 1926: 84

Name based on Savigny's figure and an unknown number of specimens from Suez. See under *isseli*.*caudata* Issel, 1869 (*Falimulla*)

Fig. 73

Savigny 1817: pl. 4, fig. 25

Issel 1869: 340

Name based on Savigny's figure and 3 specimens from Suez, now in MNHN. One shell in coll. Savigny.

Name based on Savigny's figure and a specimen from Suez, now in MNHN. One shell in coll. Savigny.

Name based on Savigny's figure and a specimen from Suez, now in MNHN. One shell in coll. Savigny.

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Name based on Savigny's figure and a specimen from Suez, now in MNHN. One shell in coll. Savigny.

Issel 1869: 177

Name based on Savigny's figure and a specimen from Suez. There are two shells with this locality in the Issel coll. in MGD. One specimen in coll. Savigny.

*clypeomorus* Jousseaume, 1888 (*Clypeomorus*)

Fig. 40-41

Savigny 1817: pl. 4, fig. 10

Jousseaume 1888: 171

Name based on Savigny's figure and an unknown number of specimens from the southern Red Sea. In the Jousseaume coll. (MNHN), there are 33 shells from Massawa and 12 shells from Obok. Two shells in coll. Savigny.

*coenobita* Vaillant, 1865 (*Mytilus*)

Fig. 12

Savigny 1817: pl. 11, fig. 3

Vaillant 1865: 115, 122

Name based on Savigny's figure and several specimens from Suez, now in MNHN. One specimen in coll. Savigny.

*concentrica* Audouin, 1826 (*Doris*)

Fig. 97

Savigny 1817: Gastéropodes pl. 1, fig. 5

Audouin 1826: 14; 1828: 128

Name based on Savigny's figure. No material left.

*corbieri* Jonas, 1846 (*Chama*)

Fig. 18

Savigny 1817: pl. 14, fig. 8

Jonas 1846c: 126

Name based on Savigny's figure. Two complete specimens in coll. Savigny.

*craticulata* Issel, 1869 (*Odontostomia*)

Fig. 75

Savigny 1817: pl. 3, fig. 39

Issel 1869: 180

Name based on Savigny's figure and subfossil specimens, which could not be traced in MGD (Genoa). One shell in coll. Savigny.

*curvieri* Audouin, 1826 (*Emarginula*)

Fig. 89

Savigny 1817: pl. 1, fig. 9

Audouin 1826: 27; 1828: 152

Name based on Savigny's figure. No material left.

*dautzenbergi* Pallary, 1926 (*Donovania*)

Fig. 37

Savigny 1817: pl. 4, fig. 20

Pallary 1926: 71

Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.

*desgenettii* "Risso" Audouin, 1826 (*Bulla*)

Fig. 55

Savigny 1817: pl. 5, fig. 6

Audouin 1826: 39; 1828: 178

Name based on Savigny's figure. Five shells in coll. Savigny.

*desmarestii* Audouin, 1826 (*Rissoa*)

Fig. 91

Savigny 1817: pl. 3, fig. 21

Audouin 1826: 36; 1828: 171

Name based on Savigny's figure. No material left.

*doliiformis* Pallary, 1926 (*Pyrgulina*)

Fig. 74

Savigny 1817: pl. 3, fig. 42-43

Pallary 1926: 63

Name based on Savigny's figure and several specimens from Suez, which could not be traced. Five shells in coll. Savigny.

*dorbiignii* Audouin, 1826 (*Rissoa*)

Fig. 68

Savigny 1817: pl. 3, fig. 22

Audouin 1826: 36; 1828: 171

Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.

*dorbiignii* Audouin, 1826 (*Scissurella*)

Fig. 63

Savigny 1817: pl. 5, fig. 30

Audouin 1826: 42; 1828: 183

Name based on Savigny's figure. Five shells in coll. Savigny.

- doriae* Issel, 1869 (*Stomatella*) Fig. 48  
Savigny 1817: pl. 5, fig. 8  
Issel 1869: 228  
Name based on Savigny's figure and 10 specimens from Suez, which could not be traced in MGD. Seven shells in coll. Savigny.
- draparnaudi* Audouin, 1826 (*Tricolia*) Fig. 46  
Savigny 1817: pl. 5, fig. 19  
Audouin 1826: 41; 1828: 181  
Name based on Savigny's figure. Two shells in coll. Savigny.
- elata* Semper, in Issel, 1869 (*Scaliola*) Fig. 84  
Savigny 1817: pl. 3, fig. 15  
Issel 1869: 330  
Name based on Savigny's figure. Fifteen shells in coll. Savigny.
- elegans* Audouin, 1826 (*Tritonia*) Fig. 94  
Savigny 1817: Gastéropodes pl. 2, fig. 1  
Audouin 1827: 15; 1828: 130  
Name based on Savigny's figure. No material left.
- eroopolitanus* Issel, 1869 (*Turbo*) Fig. 24  
Savigny 1817: pl. 5, fig. 27  
Issel 1869: 219  
Name based on Savigny's figure and one specimen from Suez which could not be traced in MGD. Six shells in coll. Savigny.
- erythraea* Hupé, 1854 (*Blainvillia*) Fig. 94  
Savigny 1817: pl. 8, fig. 6  
Hupé 1854: 223  
Name based on Savigny's figure. Two valves in coll. Savigny.
- erythraea* Issel, 1869 (*Nassa costulata* var.) Fig. 44  
Savigny 1817: pl. 6, fig. 4  
Issel 1869: 126  
Name based on Savigny's figure and specimens from Suez which could not be traced in MGD. One shell in coll. Savigny.
- erythraea* Issel, 1869 (*Lucina*) Fig. 20  
Savigny 1817: pl. 8, fig. 8  
Issel 1869: 84, pl. 1, fig. 9  
Name based on Savigny's figure and 3 specimens from Suez which could not be traced in MGD. One shell in coll. Savigny.
- erythraea* Issel, 1869 (*Arca lactea* var.)  
Savigny 1817: pl. 10, fig. 7  
Issel 1869: 89  
Name based on Savigny's figure and 6 specimens from Suez. Six paired valves in coll. Savigny.
- farrei* Landrin, 1865 (*Helix*) Fig. 21  
Landrin 1865: 2, fig. 1-3  
Name based on a shell from the Savigny coll., not depicted in the atlas. Holotype in coll. Savigny.
- ferussacii* Audouin, 1826 (*Scalaria*) Fig. 81  
Savigny 1817: pl. 3, fig. 13  
Audouin 1826: 35; 1828: 169  
Name based on Savigny's figure. One shell in coll. Savigny is considered to be the holotype.
- feuilletii* Audouin, 1826 (*Neritina*) Fig. 28  
Savigny 1817: pl. 5, fig. 11  
Audouin 1826: 40; 1828: 179  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.
- fourierii* Audouin, 1826 (*Bulla*) Fig. 54  
Savigny 1817: pl. 5, fig. 5  
Audouin 1826: 39; 1828: 178  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.
- fremincilli* Audouin, 1826 (*Rissoa*) Fig. 67  
Savigny 1817: pl. 3, fig. 20  
Audouin 1826: 36; 1828: 170  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.
- gennesi* H. Fischer, 1901 (*Clanculus*) Fig. 49  
Savigny 1817: pl. 3, fig. 3  
Fischer 1901: 123, pl. 4, fig. 11-12  
Name based on Savigny's figure and one specimen from Djibouti, now in MNHN. Five shells in coll. Savigny.
- gentiluomini* Issel, 1869 (*Eulima*) Fig. 78  
Savigny 1817: pl. 3, fig. 32  
Issel 1869: 183  
Name based on Savigny's figure and four shells from Suez. There are 6 shells with this locality in MGD. Three specimens in coll. Savigny.
- guerini* Audouin, 1826 (*Tricolia*)  
Savigny 1817: pl. 5, fig. 24  
Audouin 1826: 41; 1828: 181  
Name based on Savigny's figure. Pallary argued that this is only a color form of *T. brongnarti*. No material left.
- girardi* Audouin, 1826 (*Bulla*) Fig. 52  
Savigny 1817: pl. 5, fig. 3  
Audouin 1826: 39; 1828: 178  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.
- hemprichi* Ehrenberg, 1831 (*Helix*) Fig. 27  
Savigny 1817: pl. 2, fig. 12  
Ehrenberg 1831: *Helix* no. 4 (no page number)  
Name based on a number of snails collected near Alexandria and on Savigny's figure. 24 shells in coll. Savigny. The Ehrenberg coll. is supposedly in Berlin.
- hemprichi* Issel, 1869 (*Trochus*) Fig. 22  
Savigny 1817: pl. 3, fig. 6  
Issel 1869: 329  
Name based on Savigny's figure. Six shells in coll. Savigny.
- horridus* Orbigny, 1826 (*Octopus*) Fig. 100  
Savigny 1817: Céphalopodes pl. 1, fig. 2  
Orbigny 1826: 144  
Name based on Savigny's figure. No material left.
- humboldtii* Audouin, 1826 (*Anatola*) Fig. 85  
Savigny 1817: pl. 5, fig. 1  
Audouin 1826: 39; 1828: 177  
Name based on Savigny's figure. No material left.
- immaculata* Audouin, 1826 (*Doris*) Fig. 93  
Savigny 1817: Gastéropodes pl. 1, fig. 2  
Audouin 1827: 13; 1828: 126  
Name based on Savigny's figure. No material left.
- infracostata* Issel, 1869 (*Risella*) Fig. 64  
Savigny 1817: pl. 5, fig. 40  
Issel 1869: 195  
Name based on Savigny's figure and three specimens from Suez, which could not be traced in MGD. Three shells in coll. Savigny.
- isseli* Semper, in Issel, 1869 (*Risella*) Fig. 65  
Savigny 1817: pl. 5, fig. 35  
Issel 1869: 194  
Name based on Savigny's figure and several specimens from Suez and Zanzibar. There are 2 shells from Zanzibar with a label in Semper's handwriting in MGD. Five shells in coll. Savigny.
- isseli* Nevill & Nevill, 1875 (*Marginella*) Fig. 57  
Nevill & Nevill 1875: 95

New name for *Margynella pygmaea* Issel 1869, non Sowerby 1846. See *pygmaea*.

*isseli* Tryon, 1886 (*Turbonilla*)  
Tryon 1886: 339

New name for *Eulimella cingulata* Issel 1869. See this name.

*isthmocum* Issel, 1869 (*Cardium*) Fig. 16  
Savigny 1817: pl. 9, fig. 11  
Issel 1869: 74  
Name based on Savigny's figure and several specimens from Attaka, near Suez, which could not be traced in MGD. One valve in coll. Savigny.

*richardi* Audouin, 1826 (*Scalarum*) Fig. 36  
Savigny 1817: pl. 3, fig. 4  
Audouin 1826: 35; 1828: 169  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.

*kanthii* Audouin, 1826 (*Cypraea*) Fig. 33  
Savigny 1817: pl. 6, fig. 27  
Audouin 1827: 15; 1828: 190  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.

*lanourekii* Audouin, 1826 (*Pupa*) Fig. 83  
Savigny 1817: pl. 2, fig. 1  
Audouin 1826: 31; 1828: 161  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.

*heroi* Landrin, 1865 (*Helix*) Fig. 23  
Landrin 1865: 4, fig. 1-4  
Name based on a shell collected by Savigny at the Pyramides, not depicted in the atlas. Holotype in coll. Savigny.

*lessepsianus* Vaillant, 1865 (*Lithodomus*) Fig. 11  
Savigny 1817: pl. 11, fig. 1  
Vaillant 1865: 123  
Name based on Savigny's figure and several specimens from the gulf of Suez, two of which are in MNHN. One specimen in coll. Savigny.

*maroccanum* Pallary, 1926 (*Cardium*) Fig. 17  
Savigny 1817: pl. 9, fig. 10  
Pallary 1926: 109  
Name based on Savigny's figure. One specimen in coll. Savigny is considered to be the holotype.

*marmorata* Audouin, 1826 (*Doris*) Fig. 95  
Savigny 1817: Gastéropodes pl. 1, fig. 7  
Audouin 1826: 14-15; 1828: 129  
Name based on Savigny's figure. No material left.

*marginata* Pallary, 1926 (*Gemma*) Fig. 31  
Savigny 1817: pl. 5, fig. 9  
Pallary 1926: 76  
Name based on Savigny's figure. Four shells in coll. Savigny.

*carthagi* Issel, 1869 (*Alaba*) Fig. 71  
Savigny 1817: pl. 3, fig. 26  
Issel 1869: 26  
Name based on Savigny's figure and a subfossil specimen from the Red Sea, which could not be traced in MGD. Four shells in coll. Savigny.

*carthaginiensis* (Issel, 1869) (Fig. 58)  
Savigny 1817: pl. 3, fig. 26  
Audouin 1826: 51; 1828: 201  
Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.

*champra* Audouin, 1826 (*Tricolia*) Fig. 98  
Savigny 1817: pl. 5, fig. 14

Audouin 1826: 20-21; 1828: 140  
Name based on Savigny's figure. No material left.

*olivaformis* Issel, 1869 (*Turritum*) Fig. 56  
Savigny 1817: pl. 6, fig. 25  
Issel 1869: 171  
Name based on Savigny's figure and three specimens from Suez, one of which is in MGD. One shell in coll. Savigny.

*perlatus* Issel, 1869 (*Trifores*) Fig. 79  
Savigny 1817: pl. 4, fig. 4  
Issel 1869: 152  
Name based on Savigny's figure and subfossil specimens, of which one is in MGD with the data 'Red sea'. One shell in coll. Savigny. See also *savignyanus*.

*pharaonis* P. Fischer, 1871 (*Arca*) Fig. 7  
Savigny 1817: pl. 10, fig. 9  
Fischer 1871: 213  
Name based on Savigny's figure and several specimens from Suez which could not be traced. One valve in coll. Savigny.

*pharaonis* P. Fischer, 1870 (*Mytilus*) Fig. 10  
Savigny 1817: pl. 11, fig. 5  
Fischer 1870: 169  
Name based on Savigny's figure and several specimens from Suez, of which six bivalve specimens and one valve are in MNHN. One specimen in coll. Savigny.

*philippi* Issel, 1869 (*Cyclostrema*) Fig. 66  
Savigny 1817: pl. 5, fig. 33  
Issel 1869: 189  
Name based on Savigny's figure and 6 specimens from Suez which could not be traced in MGD. Two shells in coll. Savigny.

*pulvis* Issel, 1869 (*Cerithium*) Fig. 35  
Savigny 1817: pl. 4, fig. 5  
Issel 1869: 150  
Name based on Savigny's figure and one or several specimens from Suez of which one is in MGD in Genoa. One shell in coll. Savigny.

*pygmaea* Issel, 1869 (*Margynella*) Fig. 57  
Savigny 1817: pl. 6, fig. 26  
Issel 1869: 150  
Name based (with question mark) on Savigny's figure and one shell from Suez, now in MGD. Four shells in coll. Savigny.

*reticulata* Philippi, 1853 (*Scissurella*) Fig. 62  
Savigny 1817: pl. 5, fig. 29  
Philippi 1853: 38, pl. 6, fig. 11  
New name for "*Scissurella decussata* Orbigny, Audouin" (1826:42; 1828:183), not Orbigny, 1824. Therefore the name is based on Savigny's figure; Philippi also refers to specimens from the Red Sea collected by Hemprich and Ehrenberg. Four shells in coll. Savigny.

*richardi* Audouin, 1826 (*Cardium*) Fig. 14  
Savigny 1817: pl. 9, fig. 14  
Audouin 1826: 51; 1828: 201  
Name based on Savigny's figure. One specimen in coll. Savigny is considered to be the holotype.

*rissoi* Audouin, 1826 (*Tricolia*) Fig. 47  
Savigny 1817: pl. 5, fig. 18  
Audouin 1826: 41; 1828: 181  
Name based on Savigny's figure. Two shells in coll. Savigny.

*rissoi* Weinkauff, 1885 (*Rissoina*) Fig. 76  
Savigny 1817: pl. 4, fig. 1  
Weinkauff 1885: 63, pl. 15d, fig. 13  
Name based on the name 'Manzella de Risso' Audouin (1828: 171) and a shell from Mauritius. Two shells in coll. Savigny.



- memeriana* Issel, 1869 (*Venus*) Fig. 62  
Savigny 1817: pl. 8, fig. 3  
Issel 1869: 64  
Name based on Savigny's figure and 7 valves from Suez, now in MGD. Seven valves in coll. Savigny.
- savigniana* Audouin, 1826 (*Bursatella*) Fig. 99  
Savigny 1817: Gastéropodes pl. 2, fig. 2  
Audouin 1826: 17-18; 1828: 134  
Name based on Savigny's figure. No material left.
- savignyana* Ehrenberg, 1831 (*Helix*)  
Savigny 1817: pl. 2, fig. 20  
Ehrenberg 1831: Helix no. 9 (no page number)  
Name based on three specimens collected near Alexandria and Savigny's figure. Pallary however (1926: 47) argues that Ehrenberg's species is different from the one on Savigny's figure, which indeed depicts *Zonites algirus* (Linne), represented by 4 shells in coll. Savigny. If Ehrenberg's types proved to be lost (they are supposedly in the Berlin Museum), the present material appears to be formally available for lectotype designation if it proves necessary for nomenclature stability.
- savignyanus* delle Chiaje, 1828 (*Murex*)  
Savigny 1817: pl. 4, fig. 4  
delle Chiaje 1828: 222, pl. 49, fig. 32-34  
Name based on Savigny's figure and additional material from southern Italy, presumably lost. One shell in coll. Savigny. See also *perlatus*.
- savignyi* Blainville, 1827 (*Sepia*) Fig. 101  
Savigny 1817: Céphalopodes pl. 1, fig. 3  
Blainville 1827: 285  
Name based on Savigny's figure. No material left.
- savignyi* Deshayes, 1844 (*Planaxis*) Fig. 45  
Savigny 1817: pl. 4, fig. 29  
Deshayes 1844b: pl. 109 (with two unnumbered pages of text)  
Name based on Savigny's figure and an unknown number of specimens from Madagascar, which could not be traced. Three shells in coll. Savigny.
- savignyi* Deshayes, 1844 (*Purpura*) Fig. 30  
Savigny 1817: pl. 6, fig. 1  
Deshayes 1844a: 112  
Name based on Savigny's figure. A single specimen in coll. Savigny is considered to be the holotype.
- savignyi* Jonas, 1846 (*Cytherea*) Fig. 15  
Savigny 1817: pl. 8, fig. 17  
Name based on Savigny's figure. Eight bivalve specimens and three valves in coll. Savigny.
- savignyi* P. Fischer, 1865 (*Cerithium*) Fig. 39  
Savigny 1817: pl. 4, fig. 8  
Fischer 1865: 244  
Name based on Savigny's figure and several specimens from Suez which could not be traced. Two shells in coll. Savigny.
- savignyi* Vaillant, 1865 (*Diplodonta*) Fig. 9  
Savigny 1817: pl. 8, fig. 7  
Vaillant 1865: 124  
Name based on Savigny's figure and several specimens from El Toueneb bank, Red sea, two of which are in MNHN. Two specimens in coll. Savigny.
- savignyi* Issel, 1869 (*Littorina*) Fig. 70  
Savigny 1817: pl. 3, fig. 19  
Issel 1869: 197  
Name based on Savigny's figure and ten shells from Suez, of which seven are in MGD. Ten shells in coll. Savigny.
- savignyi* Issel, 1869 (*Marginella*) Fig. 88  
Savigny 1817: pl. 6, fig. 18
- Issel 1869: 115  
Name based on Savigny's figure and a number of specimens from Suez, of which two are in MGD. No Savigny material left.
- savignyi* P. Fischer, 1871 (*Pectunculus*) Fig. 3  
Savigny 1817: pl. 10, fig. 14  
Fischer 1871: 219  
Name based on Savigny's figure and one specimen from Suez, which could not be traced. Two shells in coll. Savigny.
- savignyi* Tapparone-Canefri, 1875 (*Fusconia*) Fig. 46  
Savigny 1817: pl. 4, fig. 14  
Tapparone-Canefri 1875: 612  
Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.
- savignyi* Morlet, 1878 (*Rimquella*) Fig. 59  
Savigny 1817: pl. 6, fig. 7  
Morlet 1878: 117, pl. 5, fig. 1  
Name based on Savigny's figure and one shell from the gulf of Suez, now in MNHN. Two shells in coll. Savigny.
- savignyi* Jousseaume, 1888 (*Mesodonta*) Fig. 5  
Savigny 1817: pl. 8, fig. 5  
Jousseaume 1888: 206  
Name based on Savigny's figure and two left valves from Cameron island, Red sea, apparently lost. One specimen in coll. Savigny.
- savignyi* Pilsbry, 1892 (*Callistochiton heterodon* var.)  
Savigny 1817: pl. 3, fig. 8  
Pilsbry 1892: 277, pl. 60, fig. 16 (copied from Savigny)  
Name based on Savigny's figure. It is therefore an objective synonym of *Chiton affinis* Issel 1869, which is based on the same figure.
- savignyi* Monterosato, 1899 (*Melagrina*) Fig. 2  
Savigny 1817: pl. 11, fig. 8-9  
Monterosato 1899: 392  
Name based on Savigny's figure and many specimens from Cyprus and Alexandria, probably in the Museo Comunale, Roma. Two specimens in coll. Savigny.
- savignyi* Pallary, 1926 (*Fissurella*) Fig. 50  
Savigny 1817: pl. 1, fig. 5; Pallary 1926: 34  
Name based on Savigny's figure and several specimens from Suez, which could not be traced. Two shells in coll. Savigny.
- savignyi* Pallary, 1926 (*Gastrochaena*) Fig. 13  
Savigny 1817: pl. 1, fig. 15; Pallary 1926: 39  
Name based on Savigny's figure and one specimen from Suez, which could not be traced. One bivalve specimen and 5 valves, some being fragmentary, in coll. Savigny.
- savignyi* Pallary, 1926 (*Littorachia*) Fig. 6  
Savigny 1817: pl. 9, fig. 5; Pallary 1926: 107  
Name based on Savigny's figure. One shell in coll. Savigny is considered to be the holotype.
- savignyi* Pallary, 1926 (*Nassa*) Fig. 90  
Savigny 1817: pl. 6, fig. 3; Pallary 1926: 87  
Name based on Savigny's figure. No material left.
- savignyi* Pallary, 1926 (*Scutus*) Fig. 92  
Savigny 1817: pl. 1, fig. 10; Pallary 1926: 35  
Name based on Savigny's figure. No material left.
- savignyi* "Philippi" Krauss, 1848 (*Siphonaria*)  
Savigny, 1817: pl. 1, fig. 1; Pallary 1926: 28  
Krauss, 1848: 61; Reeve, vol. 9, p. 5, sp. 20.  
3 syntypes in MNHN.
- savignyi* Issel, 1869 (*Rissoina*) Fig. 82  
Savigny 1817: pl. 4, fig. 3

Issel 1869: 209

Name based on Savigny's figure. A single shell in coll. Savigny is considered to be the holotype.

*Impuriana* Issel, 1869 (*Lacuna*)

Fig. 19

Savigny 1817: pl. 8, fig. 12

Issel 1869: 82

Name based on Savigny's figure and one specimen from Suez, which could not be traced in MGD. A single shell in coll. Savigny.

*issoudiniana* Issel, 1869 (*Rissoia*)

Fig. 87

Savigny 1817: pl. 3, fig. 33

Issel 1869: 205

Name based on Savigny's figure and three shells from Suez, two of which are now in MGD. No Savigny material left.

*suezensis* Issel, 1869 (*Marginella*)

Fig. 60

Savigny 1817: pl. 6, fig. 17

Issel 1869: 115

Name based on Savigny's figure and several shells from Suez, six of which are in MGD. Six shells in coll. Savigny.

*sugillata* Jonas, 1846 (*Cytherca*)

Fig. 8

Savigny 1817: pl. 9, fig. 3

Jonas 1846a: 64

Name based on Savigny's figure and two additional shells which could not be traced. Two bivalve specimens and one valve in coll. Savigny.

*therviana* Issel, 1869 (*Cingula*)

Fig. 69

Savigny 1817: pl. 3, fig. 16

Issel 1869: 199

Name based on Savigny's figure and several specimens from Suez, of which six are in MGD. About three dozen shells in coll. Savigny.

*tigrina* Audouin, 1826 (*Doris*)

Fig. 96

Savigny 1817: Gastéropodes pl. 1, fig. 3

Audouin 1826: 13; 1828: 127

Name based on Savigny's figure. No material left.

*truncata* (Férussac *ms*) Audouin, 1826 (*Physa*)

Fig. 29

Savigny 1817: pl. 2, fig. 27

Audouin 1826: 34; 1828: 166

Name based on Savigny's figure. Two shells in coll. Savigny. There are also several shells from Syria, collected by Bruguière and Olivier, in the Férussac coll. (MNHN).

*undata* Pallary, 1926 (*Risella isseli* var.)

Savigny 1817: pl. 5, fig. 35.3

Pallary 1926: 84

Name based on Savigny's figure and a number of shells from Suez, which could not be traced. See under *isseli*.

*unicolor* Dautzenberg, in Pallary, 1926 (*Cassis turgida* var.)

Savigny 1817: pl. 6, fig. 6

Pallary 1926: 88

Name based on Savigny's figure and an additional shell in Dautzenberg's private collection, which could not be traced by Abbott (1968: 199). One shell in coll. Savigny.

*venusta* Issel, 1869 (*Turbonilla*)

Fig. 34

Savigny 1817: pl. 3, fig. 34

Issel 1869: 175

Name based on Savigny's figure and three shells from Suez, now in MGD. Nine specimens in coll. Savigny.

*villar* Issel, 1869 (*Cingula*)

Fig. 80

Savigny 1817: pl. 3, fig. 17

Issel 1869: 198

Name based on Savigny's figure and six shells from Suez, four of which are in MGD. Seven shells in coll. Savigny.

*villersii* Audouin, 1826 (*Bulla*)

Fig. 53

Savigny 1817: pl. 5, fig. 4

Audouin 1826: 39; 1828: 178

Name based on Savigny's figure. Two shells in coll. Savigny.

FIGS. 1-84. Specimens from the Savigny Egyptian collection now in the Muséum National d'Histoire Naturelle in Paris, France.

1. *Spatha caillaudi* von Martens, 68 mm.

2. *Meleagrina savignyi* Monterosato, 58 mm.

3. *Pectunculus savignyi* P. Fischer, 18 mm.

4. *Unio bourguignati* Lardrin, 23 mm.

5. *Mesodesma savignyi* Jousseaume, 20 mm.

6. *Lucincha savignyi* Pallary, 33 mm.

7. *Arca pharonis* P. Fischer, 48 mm.

8. *Cytherca sugillata* Jonas, 34 mm.

9. *Diplodonta savignyi* Vaillant, 28 mm.

10. *Mitra pharonis* P. Fischer, 32 mm.

11. *Ethiodonta lessepsianus* Vaillant, 10 mm.

12. *Mitra cochobita* Vaillant, 7 mm.

13. *Gastrochaena savignyi* Pallary, 11 mm.

14. *Cardium melarchi* Audouin, 10 mm.

15. *Physa tricolor* Sav. n. sp. 35 mm.

16. *Physa tricolor* Issel, 34 mm.

17. *Physa tricolor* Sav. n. sp. 34 mm.

18. *Physa tricolor* Sav. n. sp. 35 mm.

19. *Physa tricolor* Sav. n. sp. 34 mm.

20. *Physa tricolor* Sav. n. sp. 34 mm.

21. *Physa tricolor* Sav. n. sp. 34 mm.

22. *Physa tricolor* Sav. n. sp. 34 mm.

23. *Physa tricolor* Sav. n. sp. 34 mm.

24. *Physa tricolor* Sav. n. sp. 34 mm.

25. *Physa tricolor* Sav. n. sp. 34 mm.

26. *Physa tricolor* Sav. n. sp. 34 mm.

27. *Physa tricolor* Sav. n. sp. 34 mm.

28. *Physa tricolor* Sav. n. sp. 34 mm.

29. *Physa truncata* Audouin, 5 mm.

30. *Purpura savignyi* Deshayes, 40 mm.

31. *Gena marmorata* Pallary, 4.7 mm.

32. *Gena callosa* P. Fischer, 3.2 mm.

33. *Cypraea kunthii* Audouin, 22 mm.

34. *Turbonilla venusta* Issel, 6 mm.

35. *Cerithium pulvis* Issel, 3 mm.

36. *Scalaria jomardi* Audouin, 3 mm.

37. *Donovania dautzenbergi* Pallary, 5 mm.

38. *Rissoina bertholleti* Issel, 6 mm.

39. *Cerithium savignyi* P. Fischer, 40 mm.

40. *Clypeomorus clypeomorus* Jousseaume, 18 mm.

41. *Clypeomorus clypeomorus* Jousseaume, 9 mm.

42. *Fasciolaria audouini* Jonas, 135 mm.

43. *Fasciolaria savignyi* Tapparone-Canevari, 30 mm.

44. *Nassa erythraea* Issel, 9 mm.

45. *Planaxis savignyi* Deshayes, 17 mm.

46. *Tricolia draparnaudii* Audouin, 6 mm.

47. *Tricolia rissoi* Audouin, 7 mm.

48. *Stomatella doriae* Issel, 4 mm.

49. *Clanculus gennesii* H. Fischer, 8 mm.

50. *Fissurella savignyi* Pallary, 13 mm.

51. *Chiton affinis* Issel, 9 mm.

52. *Bulla girardi* Audouin, 2.5 mm.

53. *Bulla villersii* Audouin, 1.25 mm.

54. *Bulla fourieri* Audouin, 2.6 mm.

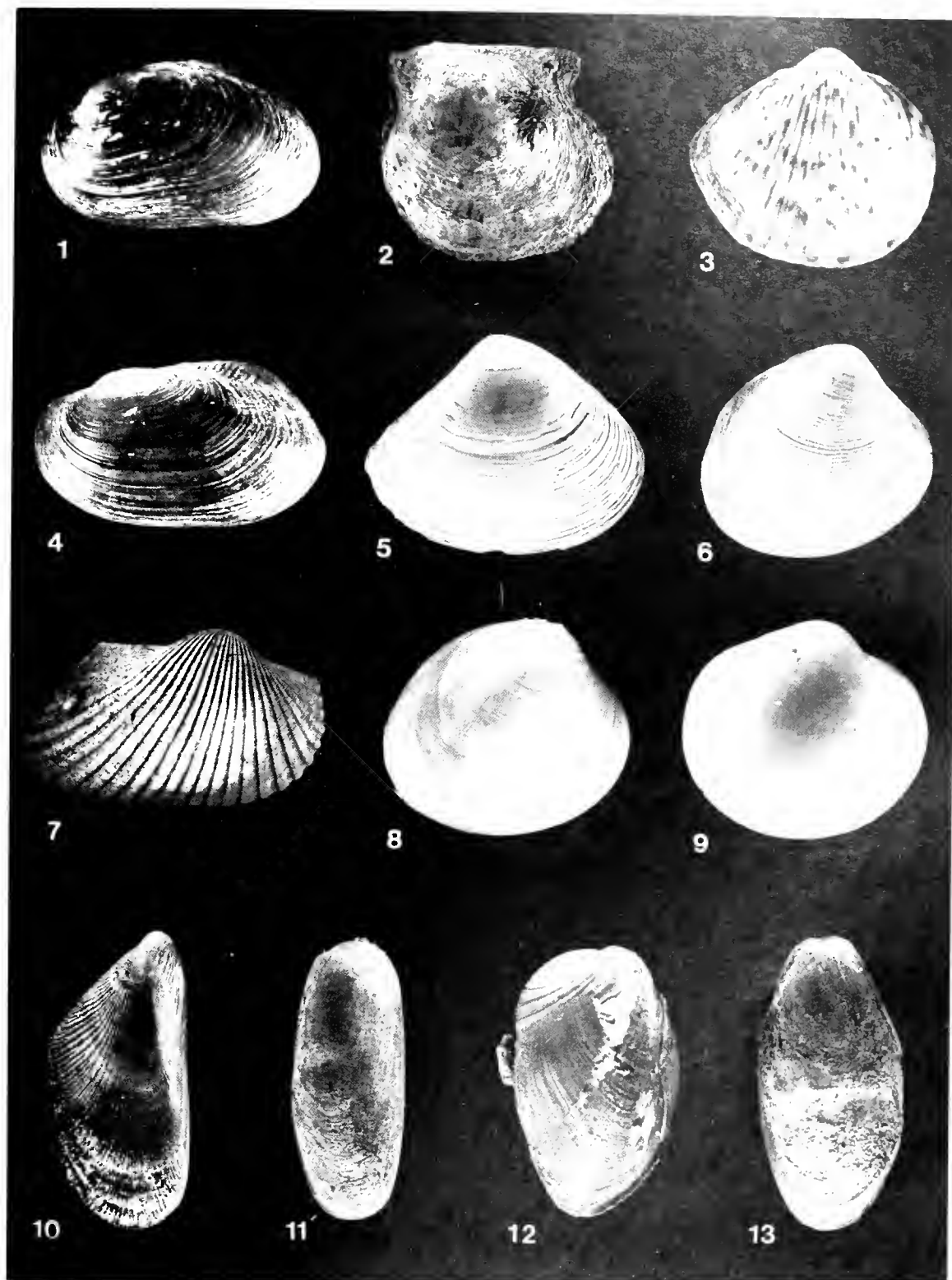
55. *Bulla desgenettii* Audouin, 1.8 mm.

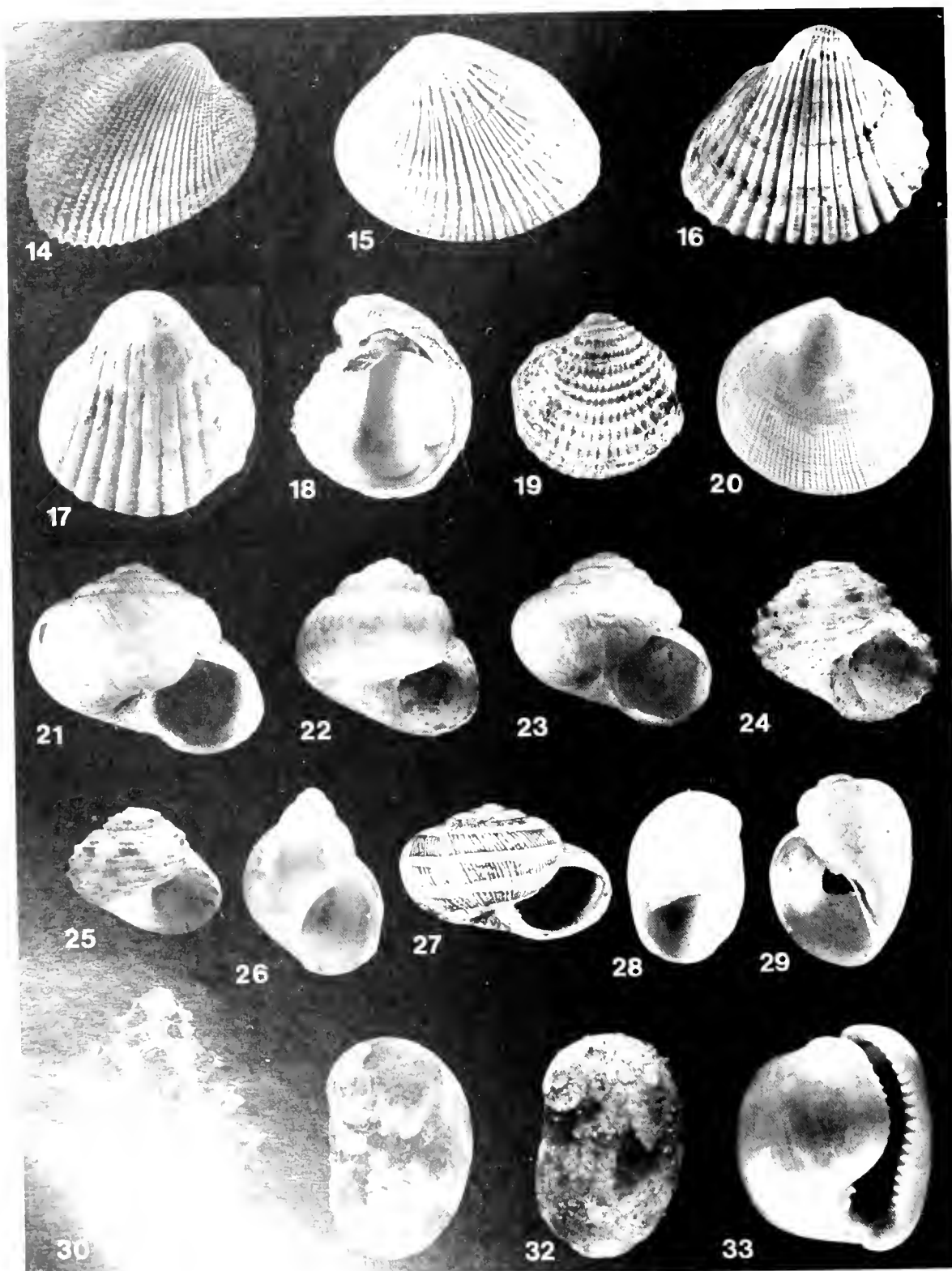
56. *Tornatina olivaeformis* Issel, 3.4 mm.

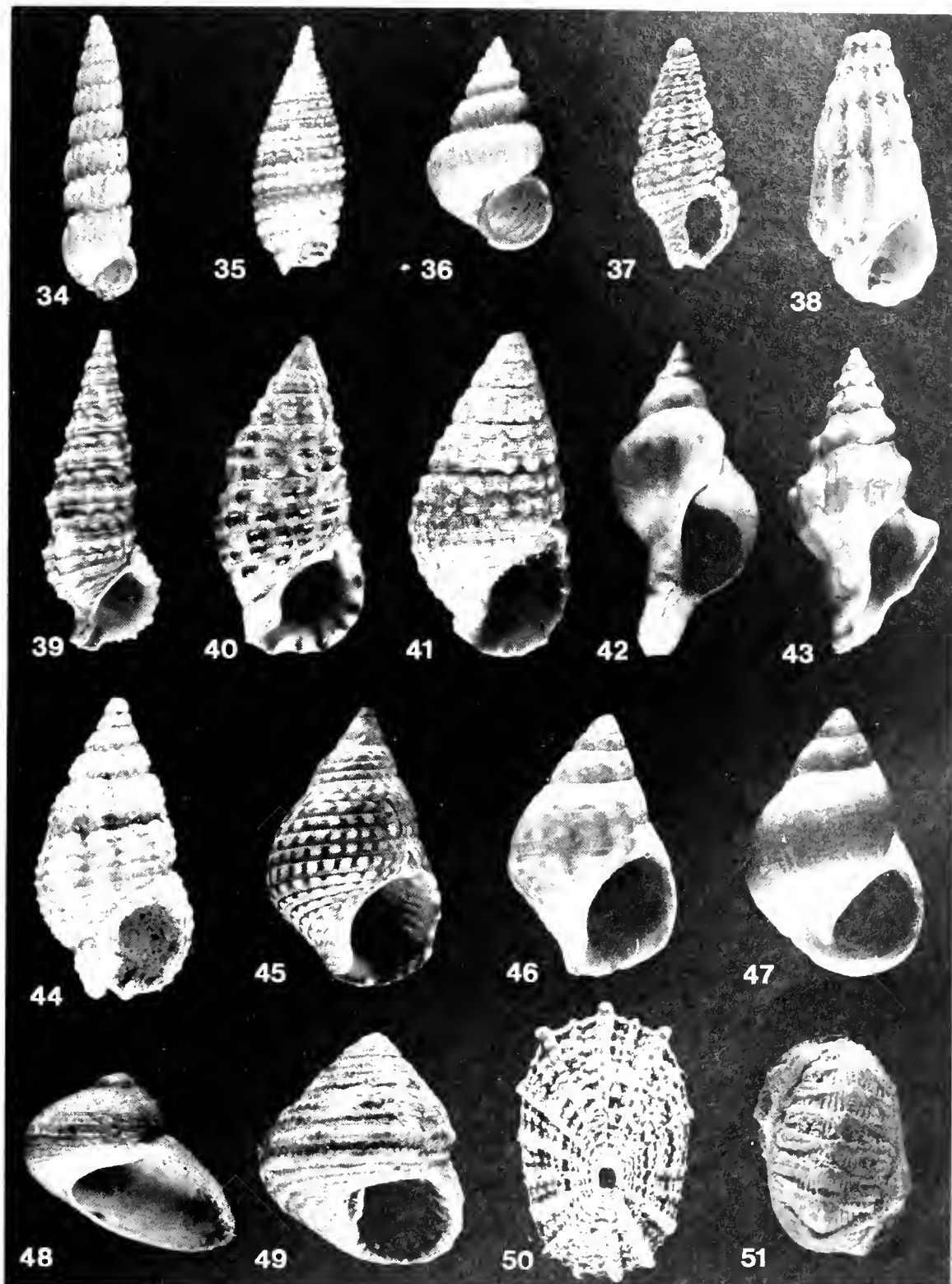
57. *Marginella isseli* Nevill & Nevill, 1.4 mm.

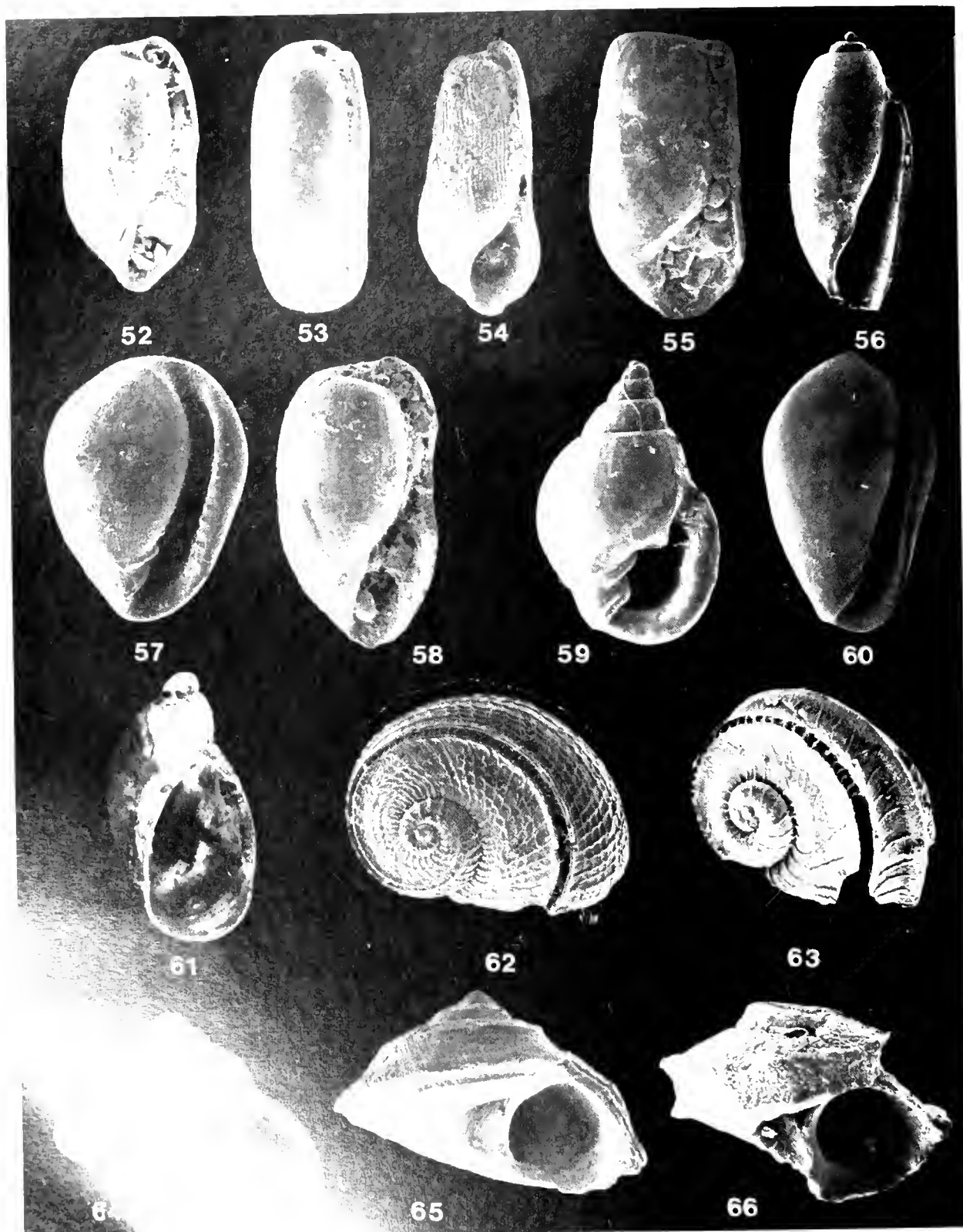
58. *Bulla mongii* Audouin, 1.6 mm.

59. *Ringicula savignyi* Morlet, 2.8 mm.

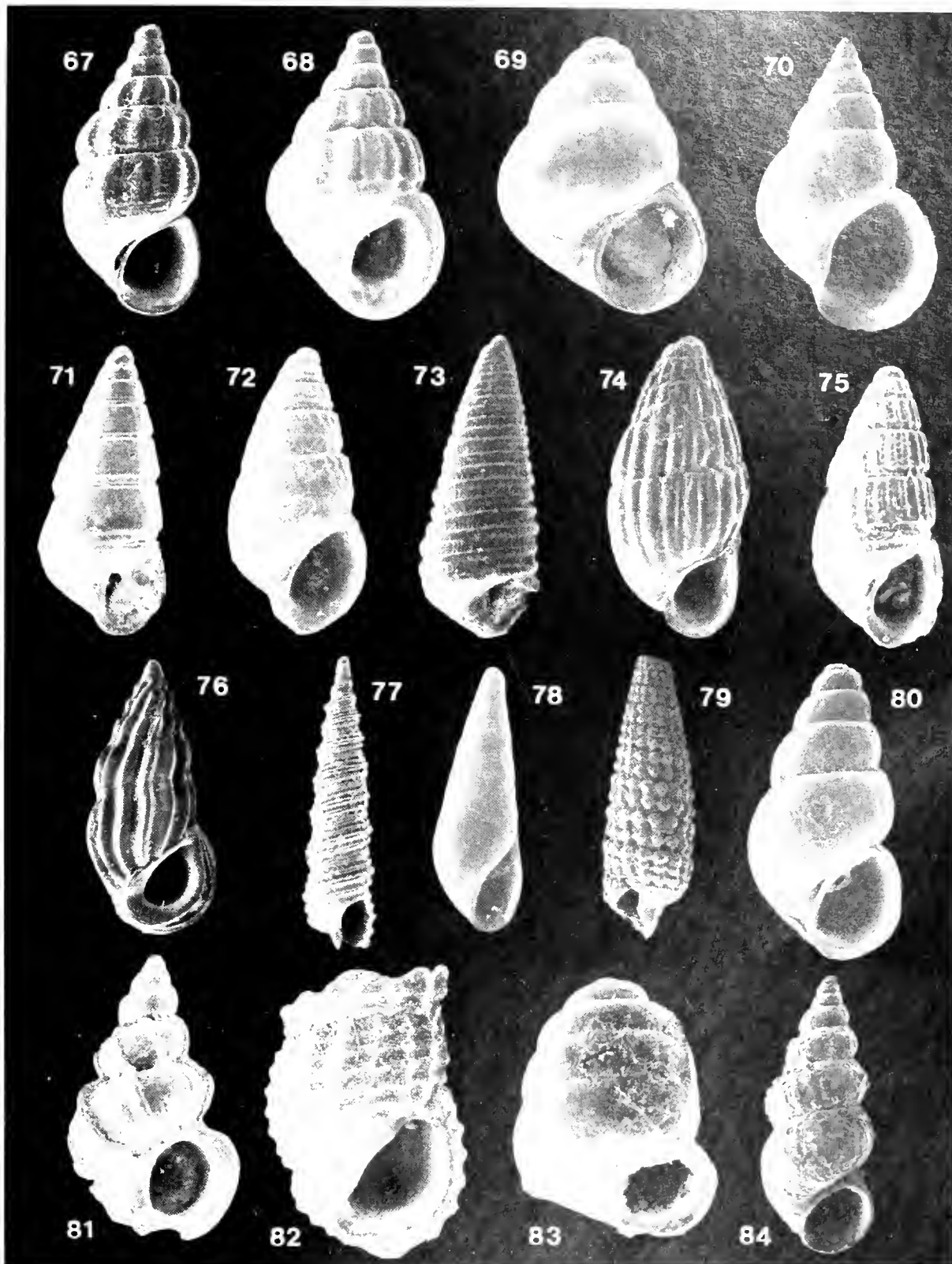






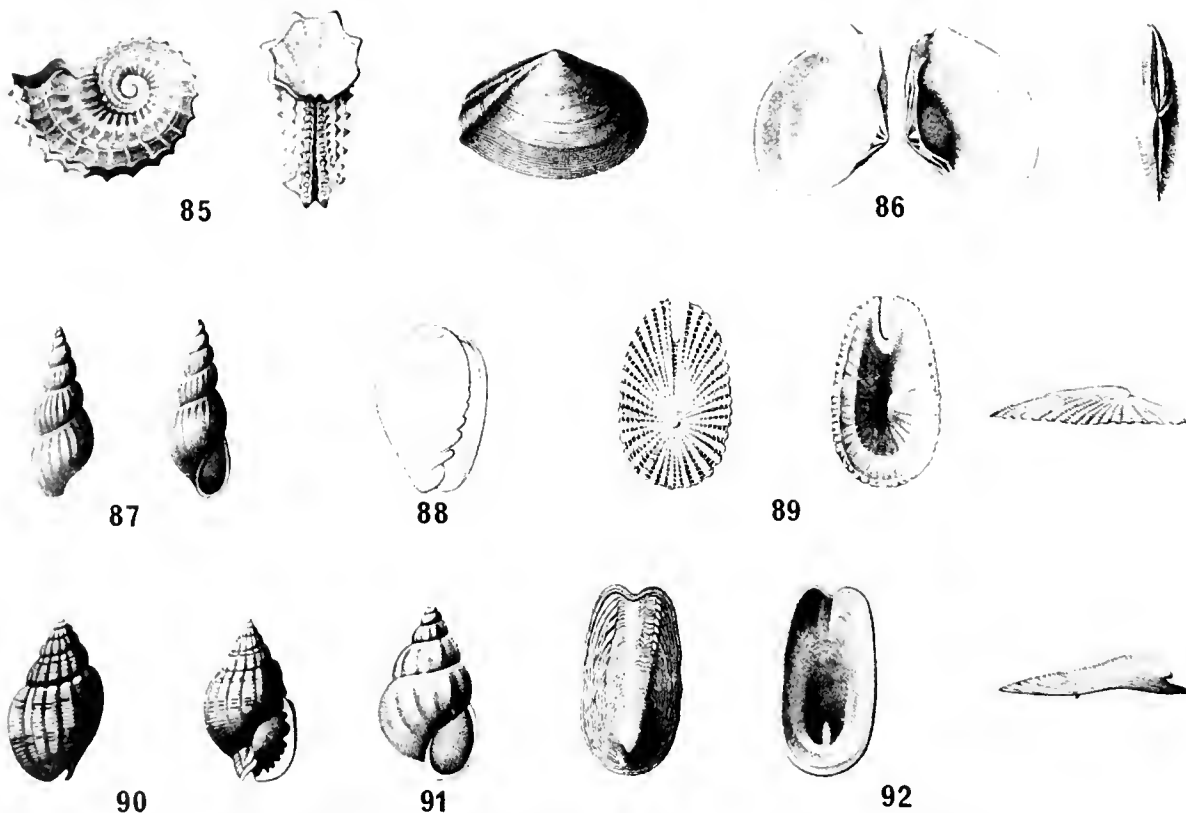






60. *Marginella sueziensis* Issel, 2.95 mm.  
 61. *Succinea aegyptiaca* Ehrenberg, 6.5 mm.  
 62. *Scissurella reticulata* Philippi, 1.75 mm.  
 63. *Scissurella dorbignii* Audouin, 1.75 mm.  
 64. *Risella infracostata* Issel, 1.15 mm.  
 65. *Risella isseli* Semper in Issel, 1.15 mm.  
 66. *Cyclostrema philippi* Issel, 1.6 mm.  
 67. *Rissoa freminvillii* Audouin, 3.0 mm.  
 68. *Rissoa dorbignii* Audouin, 2.5 mm.  
 69. *Cingula tiberiana* Issel, 1.25 mm.  
 70. *Litiopa savignyi* Issel, 2.55 mm.  
 71. *Alaba martensi* Issel, 2.3 mm.  
 72. *Odontostomia clysmatica* Issel, 2.7 mm.

73. *Eulimella cingulata* Issel, 2.6 mm.  
 74. *Pyrgulina dolliformis* Pallary, 2.1 mm.  
 75. *Odontostomia craticulata* Issel, 2.05 mm.  
 76. *Rissoina rissoi* Weinkeuff, 3.4 mm.  
 77. *Cerithium bacillum* Issel, 3.75 mm.  
 78. *Eulima gentiliuomiana* Issel, 2.6 mm.  
 79. *Triforis perlatus* Issel, 4.7 mm.  
 80. *Cingula villae* Issel, 2.0 mm.  
 81. *Scalaria ferussacii* Audouin, 1.95 mm.  
 82. *Rissoina seguenziana* Issel, 2.8 mm.  
 83. *Pupa lamarekii* Audouin, 2.2 mm.  
 84. *Scaliola elata* Semper in Issel, 2.05 mm.



FIGS. 85-92. Types figures copied from Savigny (no type material found in Savigny collection).

85. *Anatola humboldti* Audouin, 35 mm (?).  
 86. *Pristis audouini* Jousseaume, 31 mm.  
 87. *Rissoa sismondiana* Issel, 2.5 mm.

88. *Marginella savignyi* Issel, 4 mm.  
 89. *Emarginula cuvieri* Audouin, 9.5 mm.  
 90. *Nassa savignyi* Pallary, 9 mm.  
 91. *Rissoa desmarestii* Audouin, 3 mm.  
 92. *Scutus savignyi* Pallary, 7 mm.

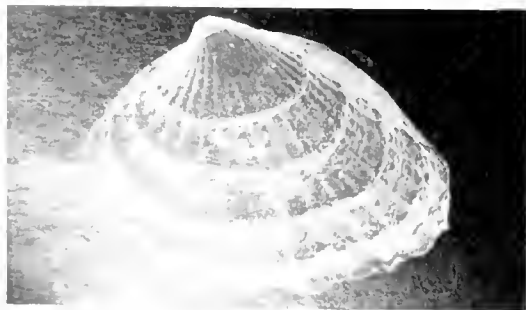


FIG. 96. *Nautilus*, 3.9 mm.

FIGS. 96-103. Savigny's unpublished color vellums of opisthobranchs and cephalopods in Bibliothèque Centrale, MNHN. Only black and white prints were previously published.

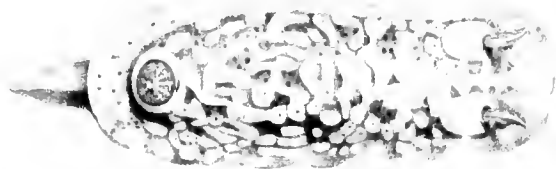




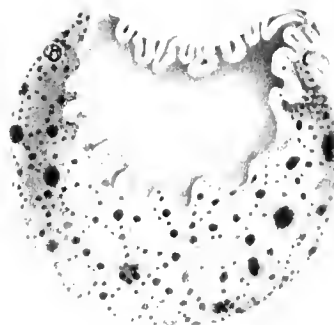
96, *Doris immaculata* Audouin, 46 mm.



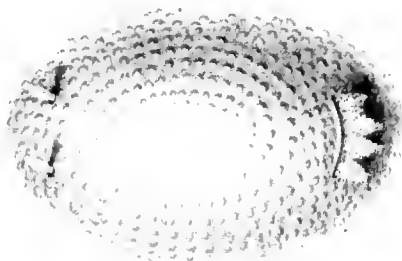
97, *Tritonia elegans* Audouin, 50 mm.



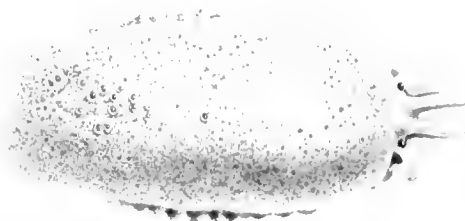
98, *Doris marmorata* Audouin, 30 mm.



99, *Doris tigrina* Audouin, 22 mm.



100, *Doris concentrica* Audouin, 21 mm.



101, *Pleurobranchus oblongus* Audouin, 30 mm.



102, *Bursatella savignyana* Audouin, 130 mm.



103, *Octopus horridus* Orbigny, mantle length 30 mm.

FIG. 94. *Blainvillia erythraea* Hupé, 58 mm.FIG. 95. *Sepia savignyi* Blainville, mantle length 85 mm. From an unpublished color vellum in the Bibliothèque Centrale, MNHN.

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## SHELL MICROSTRUCTURE OF *CORBICULA FLUMINEA* (BIVALVIA: CORBICULIDAE)<sup>1</sup>

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### ABSTRACT

*The shell microstructure of Corbicula fluminea was examined using scanning electron microscopy. The interface between the periostracum and calcareous shell, and a marginal periostracal loop, are described with a discussion of possible functions. Surface morphology of shells with periostracum chemically removed revealed periodic concentric surface ridges. The complex crossed-lamellar crystalline arrangement of the shell is confirmed.*

Shell structure of bivalves in the genus *Corbicula* (Mühlfeld, 1811) has been examined by several investigators (Tsuji, 1960; Toots and Fox, 1972; Taylor et al., 1973; Mackie, 1978). Tsuji (1960) reported that three shell layers (periostracum, prismatic and pearl [nacreous of other authors]) are present in *C. japonica* Prime, 1864, collected from brackish waters of the Tose River at Tsu, Japan.

Taylor et al. (1973) reported that shells of *Corbicula fluminea* (Müller, 1774), *C. occidentalis* (Deshayes, 1854), *C. cuneiformis* (Sowerby, 1817) and the fossil species *C. cordata* (Morris, 1854) are composed totally of aragonitic calcium carbonate. Toots and Fox (1972) found that aragonite, as is typical of this mineral through geologic time, had metamorphosed to calcite in fossil shells of *Corbicula (Leptesthes) fracta* collected in the Upper Cretaceous strata of Wyoming.

The outer calcareous shell layers of *Corbicula fluminea* and *C. occidentalis* are arranged in a finely crossed lamellar pattern, the inner layers are complex crossed lamellar and an indistinct myostracum occurs at the pallial line (Taylor et al., 1973). The complex crossed lamellar layer of *C. fluminea* and *C. occidentalis* consists of laths arranged in regular columns as in the Limopsacea (Taylor et al., 1969).

Mackie (1978) examined the shell structure and mineralogy of *Corbicula fluminea* in a comprehensive ultrastructural study of the freshwater Sphaeriacea. *Corbicula fluminea* has the thickest shell of the 23 species of sphaeriaceans studied. Mackie reported that the individual layers of the complex crossed lamellae, which are found in all Sphaeriacea, are inclined in opposite directions. No pallial myostracum, nacreous or outer prismatic layer is present. Mackie (1978) postulated that thicker-shelled species of sphaeriaceans have correspondingly thicker periostraca that protect the shell from dissolution in acid waters of organically enriched habitats in which they are found (Ingram et al., 1953; Mackie and Qadri, 1973).

No single study has carefully examined the ultrastructure of the interior and exterior surface features of the shell of the Asiatic clam. The present paper presents such an analysis of the shell of *Corbicula fluminea*, using scanning electron microscopy. The outer surface morphology is emphasized.

### MATERIALS AND METHODS

Specimens of *Corbicula fluminea* were collected, through the kindness of Dr. Ralph W. Taylor, from Tygarts Creek, Carter County, Kentucky, in October 1978. The bivalves were first relaxed in 7% magnesium chloride or propylene phenoxylol solutions. Periostracum was then removed with a 5% sodium hypochlorite

<sup>1</sup>University of Delaware College of Marine Studies Contribution No. 155.

solution. Shells were washed in distilled water, dehydrated through 70% ethanol and placed in a hot air oven (73°C) for 48 hours to dry. Shells were then fractured and shell fragments were selected from the posterior and anterior adductor muscle scars, the hinge and ligament, the growing edge, the outer surface near the growing edge, the pallial line, and the purple inner surface. Dried shell fragments were mounted on aluminum SEM pin stubs with double adhesive tape and silver paint and stored in the hot air oven (73°C) until coated with metal.

Fractured shells with intact periostracum were dehydrated in a series of increasing concentrations of ethanol solutions to 100% in which they were stored. Periostracum was also prepared on whole shells by fixation in 3% gluteraldehyde for 7 days. Shells were fractured and fragments placed in 50% ethanol (5 min.) and 100% ethanol (28 hrs.). All specimens were dried in a Denton DCP-1 critical point drying apparatus using carbon dioxide as a transfer agent. Specimens were then mounted on pin stubs.

Mounted specimens were coated with a thin layer of gold in a Denton Vacuum Evaporator and examined in a Philips PSEM 501 SEM.

## RESULTS

A well-developed periostracum covers the calcareous shell of *Corbicula fluminea*. This layer consists of an extremely smooth external surface, is internally homogenous, and averages 10  $\mu\text{m}$  in thickness. It is firmly conjoined with the underlying aragonitic crystals.

The periostracum terminates along the ventral shell margin in a reflective loop before in-

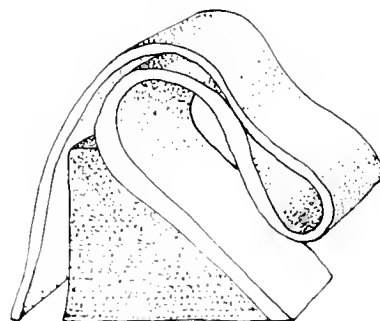


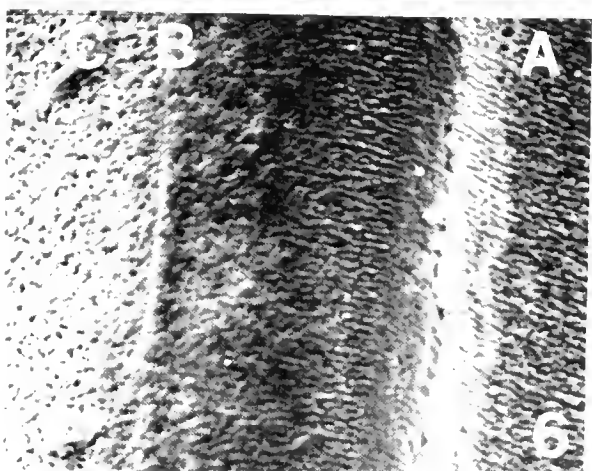
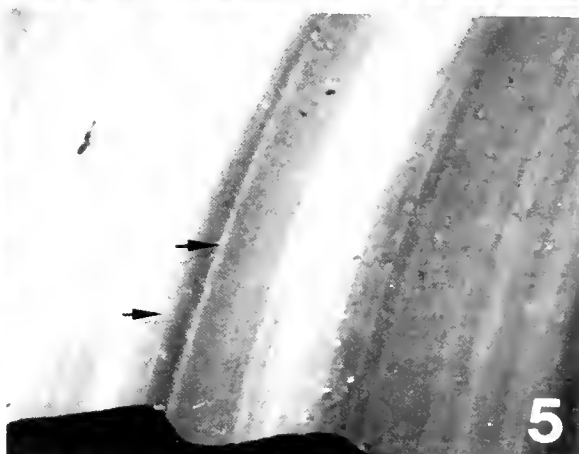
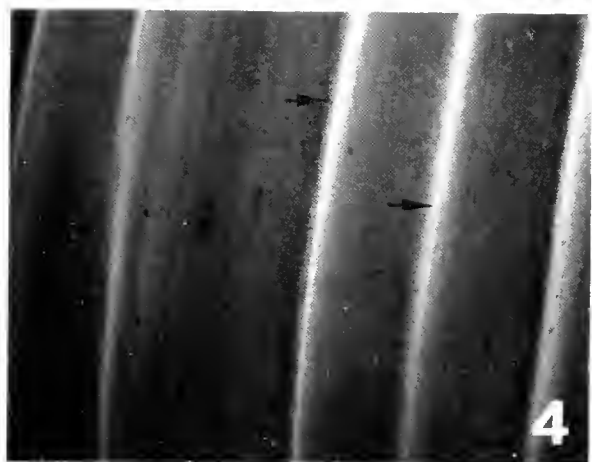
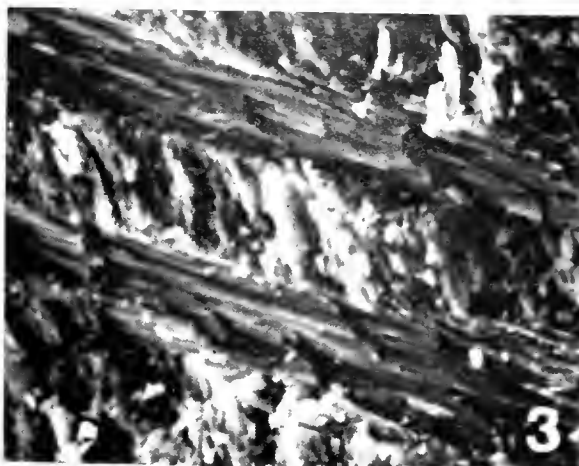
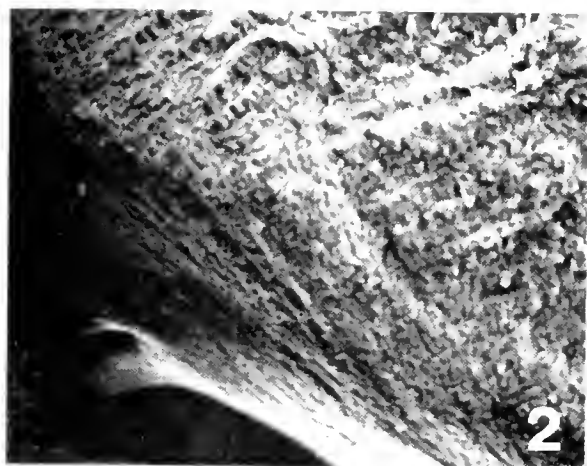
FIG. 1. Periostracal loop at ventral shell margin. Direction of growth to the top. Horizontal field width = 255  $\mu\text{m}$ .

gressing to the secretory mantle (Fig. 1). Thus, upon emergence from the mantle, the periostracum remains disattached from internal calcareous shell and extends up to 580  $\mu\text{m}$  beyond the shell edge in a loop that often bends back over the outer shell margin. Where the periostracum closely overrides the outer shell surface, the attachment is very tight and rarely is this organic layer seen to peel away from the calcareous exoskeleton.

Ultrastructural examination of fractured shell fragments confirms the complex crossed lamellar structure reported by Taylor et al. (1973) and Mackie (1978) (Fig. 2). Bands of crystalline laths are arranged approximately normal to each other. Individual layers or bands have an average thickness of 10  $\mu\text{m}$  (Fig. 3) while individual crystalline laths are approximately 0.7  $\mu\text{m}$  in diameter.

A cursory examination of the outer surface of shells from which periostracum has been removed with sodium hypochlorite reveals annulations or major ridges visible to the unaided eye that are separated by fine, concentric striations

FIGS. 2-7. 2, Radially fractured shell of *Corbicula fluminea* demonstrating complex crossed lamellar structure. Direction of growth to the right. Horizontal field width = 900  $\mu\text{m}$ . 3, Normally arranged crystalline laths composing the complex crossed lamellar shell. Direction of growth to the right. Horizontal field width = 8  $\mu\text{m}$ . 4, Outer shell surface, with periostracum removed, showing concentric major annulations (arrows), unequally spaced, and finer, subannular concentric striations between major annuli. Direction of growth to the right. Horizontal field width = 5.3 mm. 5, Shell surface, with periostracum removed, of a fractured specimen. Two growth zones are found in association with the major annulus (arrow). Direction of growth to the right. Horizontal field width = 2.4 mm. 6, Growth zones demonstrating rugose, perforate and smooth, and then rugose-perforate, and grooved and then smooth, terminating in a small ridge (A), a small ridge (B), and a small ridge (C). Direction of growth to the left. Horizontal field width = 330  $\mu\text{m}$ . 7, Rugose, perforate laths, with concentric striations, organized into radial ridges and grooves with surface perforations. Direction of growth to the left. Horizontal field width = 82  $\mu\text{m}$ .



(Fig. 4). Under higher magnification (Fig. 5) three major striations are often found in association with each large concentric annula-

tion. The surface morphology of a single major ridge system (Fig. 6) changes with growth, showing different patterns of rugosity that ap-

perforations to be associated with cessation of growth that alternate with smooth areas at the apparent beginning of renewed shell growth. The largest region of rugose shell was found in areas preceding an apparent growth halt (Fig. 7). This region demonstrated an overall pattern of perforations and grooves that are radially oriented. The grooves were either interrupted or anastomosing and had an average width of 1-2  $\mu\text{m}$ . Perforations within this zone (Fig. 8) were of various sizes, ranging from the irregularly ovoid largest holes measuring  $0.75 \times 1.00 \mu\text{m}$  at their greatest dimensions, to the smallest, more circular holes with an average

diameter of 0.5  $\mu\text{m}$ . The largest perforations usually occurred at the bottom of the radial grooves. The small perforations were usually found on walls bordering grooves. No perforations penetrated very deeply into the interior of the shell (Fig. 9). This rugosity is a natural occurrence on the calcareous shell of *Corbicula fluminea* and is not an artifact caused by chemical removal of the periostracum. This is evidenced by the alternating smooth areas.

The zone of perforated grooves terminates in a narrow (approximately 20-30  $\mu\text{m}$ ) band of thick, radially arranged microstructures (Fig. 10). This calcareous band is continuous with the

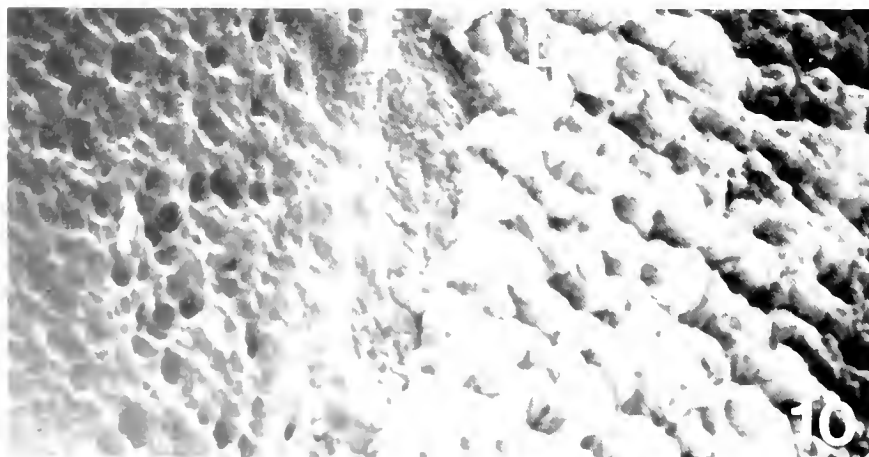
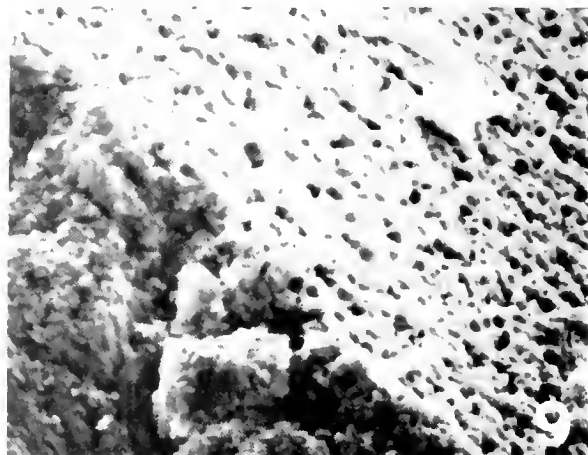
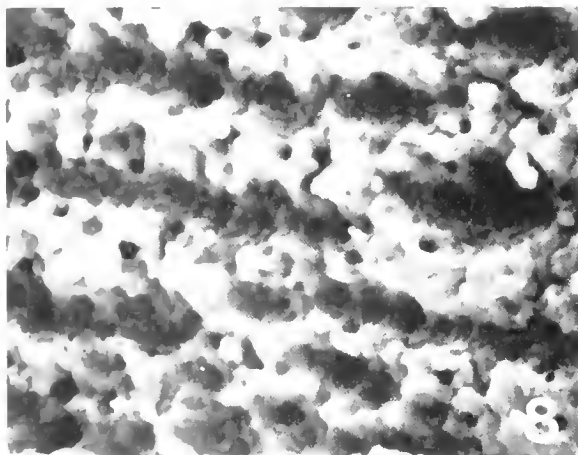


FIG. 8, 9, 10. Scanning electron micrographs demonstrating varying sizes of perforations. Direction of growth to the right. 8, Perforations in shell. 9, Fracture section of shell with periostracum removed. Note superficial perforations. Horizontal field width = 82  $\mu\text{m}$ . 10, Thick, concentric band (D) terminating the ridge. The ridge is to be laid down from beneath this band. Direction of growth to the left. Horizontal field width = 82  $\mu\text{m}$ .

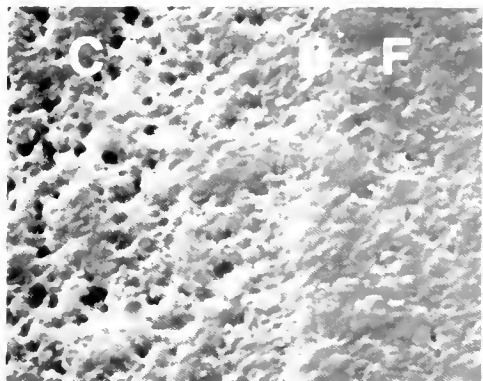


FIG. 11. The 5  $\mu\text{m}$  ridge (B) separating smooth band (F) from rugose band (C) of shell. Perforations of the rugose band are not organized into ridge-groove patterns at this stage. The smooth band has few, scattered perforations. Direction of growth to the right. Horizontal field width = 65  $\mu\text{m}$ .

radial-perforate zones, and has few perforations. The leading edge of this zone apparently represents the end of a growing period.

A concentric ridge averaging 5  $\mu\text{m}$  in width was found 110  $\mu\text{m}$  from the band of apparent growth cessation (Fig. 6). Between these two points, three transitional surface patterns were found; a band of smooth surfaced shell averaging 25  $\mu\text{m}$  in width with diffuse perforations, a 25  $\mu\text{m}$ -wide band of grooved, perforate surface similar to that preceeding the thickened calcium band before the apparent growth pause, and a 60  $\mu\text{m}$  wide band of smooth surfaced shell that terminates in the 5  $\mu\text{m}$ -wide ridge.

Immediately following the 5  $\mu\text{m}$  ridge, the shell surface becomes more rugose with perforations averaging 2–4  $\mu\text{m}$  in diameter (Fig. 11). These perforations are heterogeneous but gradually gain organization as they meld with the ridge-groove pattern found later in the growth period (Figs. 6, 7, and 8) and terminate in the thickened surface sculpture (Fig. 10).

## DISCUSSION

The periostracum tightly fills the irregular contours of the underlying calcareous shell surface as shown in Figure 10. Presumably the periostracum has fully polymerized prior to the initiation of calcium carbonate deposition on this organic template (Waite and Wilbur, 1976), so that this intimate association is more likely a

result of aragonitic nuclei being deposited in rugosities of a preformed periostracal mold. In any event, the tight fit between periostracum and calcareous shell typically leaves an intact outer organic layer over the aragonitic shell and the only evidence of periostracal wear occurs around the umbones.

The marginal periostracal loop is an interesting morphological feature whose function is unclear. The periostracal extension might allow free range of motion of the mantle so that upon withdrawal of the mantle the periostracum would easily follow. Thus upon adduction periostracum would form an effective seal at the shell edge.

The curvature of the periostracal loop, if maintained during mineralization might offer a mold for formation of calcareous concentric shell ridges. Loop size corresponds well with that of major concentric ridge size, lending support to this hypothesis. Extensive periostracal folding along the mantle margin occurs commonly in many marine bivalves [for example, *Arca zebra* (Waller, 1980)]. "Excess" marginal periostracum is probably a reflection of periostracal growth exceeding development of calcareous shell. This phenomenon still requires careful analysis.

Morton (1977) found that populations of *Corbicula fluminea* in Plover Cover Reservoir, Hong Kong, spawn twice a year. He pointed out that shell growth appeared to stop during these episodes as energy is redirected to gonadal development. The first spawning in the spring of the Plover Cover population was the most intensive, followed by a less intensive one in the fall or late summer (Morton, 1977). Although Morton (1977) reported no shell surface changes that correspond to spawning seasons, if metabolism is redirected so that only gonads are developed and shell growth ceases, this halt should be reflected in the surface morphology of the shell. Fuziwara (1975, 1978) reported *Corbicula leana* spawns biannually in response to thermal stimuli and while portions of the gonad are mature throughout the year, the overall rate of gametogenesis is unknown. Jones (1981) recently reported variations in shell growth increments that correspond to thermal variation

in the marine environment. The pattern of surface shell sculpture seen in the Tygarts Creek, Kentucky, population may be the result of redirected energetics during gametogenesis and change in surface sculpture seen in Figure 10 represents the terminal period of shell growth before gonadal development or a response of the bivalve to fluctuations in thermal regime.

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## A RELIC POPULATION OF *OBOVARIA RETUSA* IN THE MIDDLE CUMBERLAND RIVER, TENNESSEE

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### ABSTRACT

*Recovery in 1980-1981 of three specimens of Obovaria retusa (Lamarck, 1819) from call piles left by commercial shellers provides additional evidence of an extant relic population of this naiad in the middle Cumberland River, Trousdale County, Tennessee.*

The form and distribution of *Obovaria retusa* (Lamarck, 1819) in the middle Cumberland River, Ohio, Cum-

berland, and Tennessee River systems. This mussel, called by the common name Golf Stick by



Boepple and Coker (1912) and known variously as Pink, Ring Pink, Ram's Horn Pink, Pink Pigtoe or Rosebud by commercial shellers, typically inhabits the deep stretches of a river having swift current and a substrate composed of coarse sand and gravel. *Obovaria retusa* has been extirpated throughout most of its former range. Stansbery (1970) stated that "A population still living in the impounded lower Tennessee [below Pickwick Dam] had apparently not reproduced since impoundment and is expected to die out. The only known breeding population of this once widespread species is a small one in the Green River near Munfordville, Kentucky." Stansbery has since commented (Personal Communication, October 1980) that the Green River population appears to be no longer viable and very possibly has been entirely eradicated. Commercial shellers still occasionally take a large old relic individual from stretches of the Tennessee River below Pickwick Dam, but the animal is extremely rare judging by the limited numbers encountered.

Prior to impoundment, *O. retusa* occurred throughout the Cumberland River "although by no means abundant anywhere" (Wilson and Clark, 1914). However, Neel and Allen (1964), in their study of the mussel fauna of the upper Cumberland River basin before impoundment, found it to be fairly common on the big stream bars below the falls. *O. retusa* was not found during a collection made by Stansbery (1969) after impoundment of the same general area surveyed by Neel and Allen (1964). Tennessee Valley Authority biologists (TVA, 1976), however, reported finding the Ring Pink (numbers and location not given) at a sheller's cook-out area during their mussel survey of the middle Cumberland River in Wilson, Trousdale, and Smith counties (CRM 270.0-305.0). Although a few valves of *O. retusa* were recovered from two prehistoric Indian rock shelter middens (Woodland Period, c. 1000 B.C. - A.D. 1000) in Smith County by Parmalee, Klippel and Bogan (1980), no fresh specimens were taken by brailing or found in sheller's cull and stock piles during their three year middle Cumberland River naiad survey in Smith County.

Examination of a series of cull and stock pile

belonging to a commercial sheller operating from a location along the Cumberland River (CRM 275.2), c. 6.5 km south of Hartsville, Trousdale County, Tennessee were made November 14, 1980 and January 8 and September 17, 1981. In addition to the various piles of shell, sorted on the basis of species, size, and/or nacre color, several hundred naiads had been discarded at the water's edge. It was in this area that the first specimen of *O. retusa* was found; it was a very large female (in mm: length, 83; height, 79, breadth, 50) and, by all appearances, old with a heavily eroded umbo and slightly deformed posterior margin (Figure 1). It is very similar in size and apparent age to those specimens taken in the Tennessee River below Pickwick Dam. The second specimen, another female and represented by the right valve, was recovered January 8, 1981 from a large cull pile of "pinks" (*Elliptio* spp., *Cyclonaias tuberculata*, *Lampsilis orbiculata*, *Epioblasma sulcata*). Measurements (mm) of this valve are as follows: length, 64, height, 60, estimated breadth of paired valves, 40.

During re-examination of these abandoned cull piles (no commercial shelling in this area since summer 1980) on September 11, 1981, the

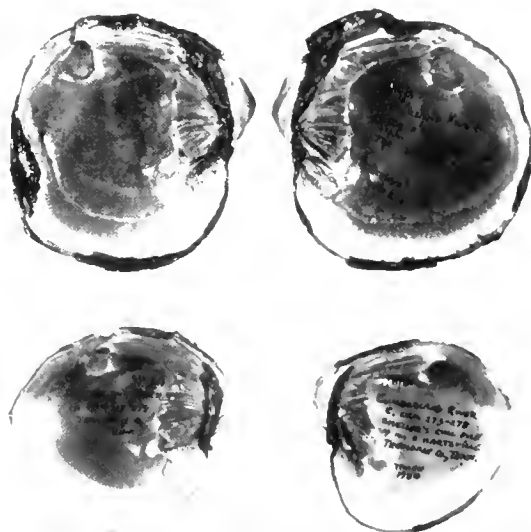


FIG. 1. Specimens of *Obovaria retusa* taken by commercial shellers, summer 1980, in the Cumberland River, Trousdale County, Tennessee. Top shell 83 mm in length.

left valve of another female was found. This specimen was slightly larger than the one represented by a right valve and measured 71 mm in length, 63 in height, and estimated 44 mm in breadth of paired valves. Diligent searches failed to locate the other valves of these two individuals (Figure 1).

Admittedly three specimens or even several do not represent a viable population, but they do provide evidence for the continued existence of *O. retusa* in the middle Cumberland River. Although the two smallest of the three specimens appear to be considerably younger than the large individual, the outer rest-lines are crowded and too obscure to establish even an estimated age with any degree of certainty. Their smaller size and the lesser extent of umbo erosion suggests individuals somewhat younger than the larger female, but it has been found that in the case of certain species (e.g. *Epioblasma brevidens*, *Cyprogenia irrorata*) or individuals that impoundment has the effect on naiads of causing the production of extremely heavy and thick but stunted shells (Parmalee, Klippel, and Bogan, 1980).

The assemblage of naiad species from this section of the river (CRM c. 273.0-278.0) where the specimens of *O. retusa* were taken exhibits some interesting differences from the one reported by Parmalee, Klippel, and Bogan (1980) at CRM 291.0-296.8. Although many species such as *Lampsilis orbiculata* appear to occur in about the same frequency in the stretch of river below Hartsville as they do upstream some 16-18 km, others, including *Actinonaias ligamentina* and *Ptychobranhus fasciolaris*, are much rarer in occurrence. In contrast, *Quadrula quadrula* appears in greater numbers below Hartsville. It is of interest to note that a relic population of *Epioblasma sulcata* continues to survive in

the Cumberland River below Hartsville; we salvaged 38 specimens (all males) of this endangered naiad from the cull piles. It is evident from the paucity of specimens taken during the past five years that *O. retusa* continues to exist only as a relic population in the middle Cumberland River and that, as Stansbery (1970) commented regarding the population of this naiad in the lower Tennessee River, it can be expected to die out.

#### ACKNOWLEDGMENTS

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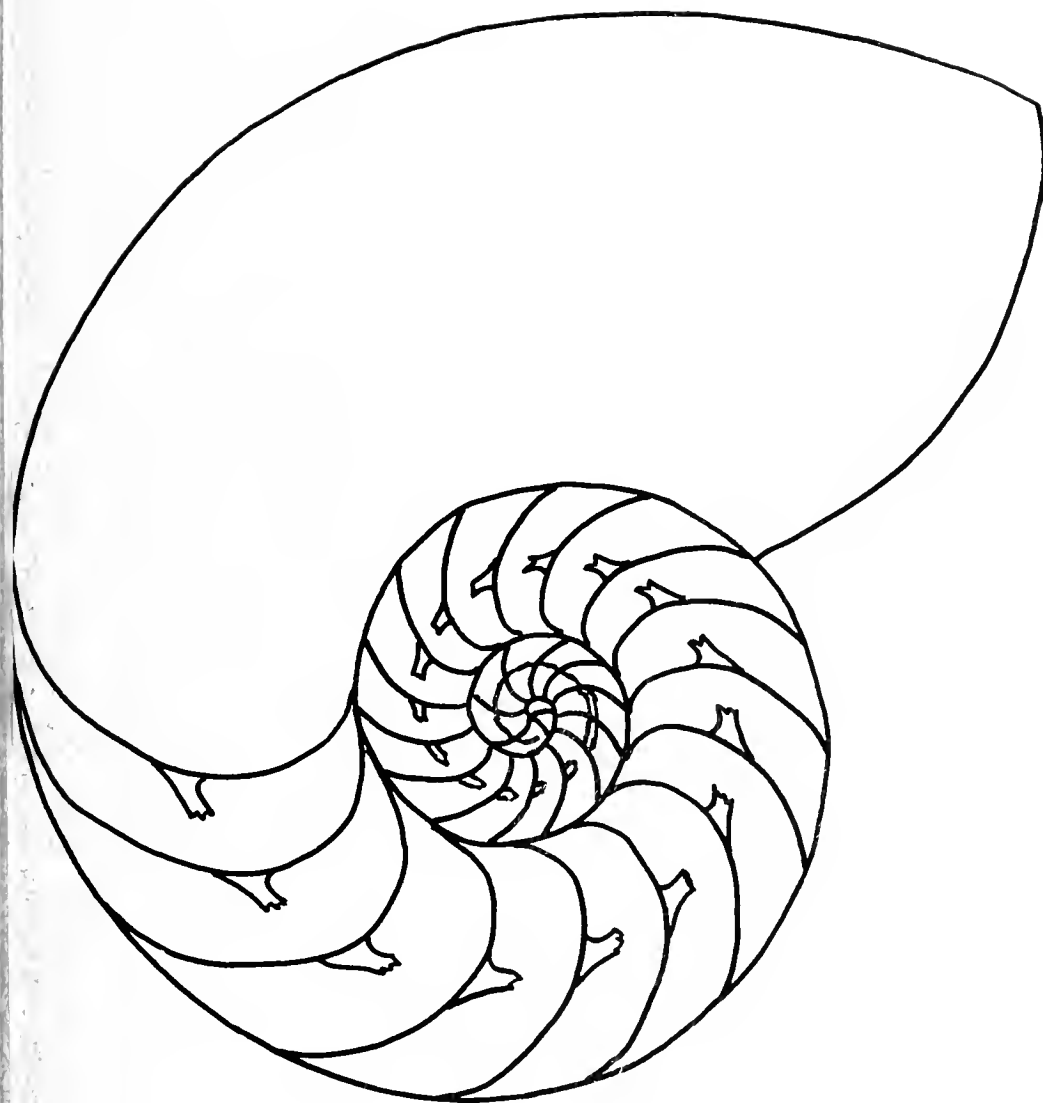
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**JOSEPH CHARLES BEQUAERT**  
1886-1982

Dr. Joseph C. Bequaert, Agassiz Professor of Zoology emeritus of the Museum of Comparative Zoology, Harvard University, died in Amherst, Massachusetts, at the age of 95, after a lingering illness, on January 12, 1982.

Dr. Bequaert was born in the small town of Thourout, near Bruges, Belgium, and as a schoolboy was interested in plants and mollusks. In 1908 he received his Ph.D. in botany from the University of Ghent, and he spent the rest of his long and productive life studying many facets of the natural world.

His first entomological field work was in the Belgian Congo where he was Entomologist for the Belgian Sleeping Sickness Commission from 1910 to 1912. He stayed on in Africa after the Commission gained control of the disease by isolating its victims, and between 1913 and 1915 he continued his botanical work, being in charge of botanical explorations for the Belgian Colonial Government. During his time in Africa he collected mollusks, many of them new, from the Congo River, throughout the jungles to the mountainous Ugandan border. This material was studied by Dr. Henry A. Pilsbry and formed the basis of his two-volume work on the mollusks of the Belgian Congo, the second volume of which was written in collaboration with Dr. Bequaert.

In 1916 Joe Bequaert immigrated to the United States, and by 1921 he was a naturalized citizen. His first position in the U.S. was at the American Museum of Natural History as Research Associate in Congo Zoology. He left the American Museum in 1922 for Boston, where he was first Instructor (1923-1925) and then Assis-

tant Professor in the Department of Tropical Medicine at the Harvard Medical School, 1925-1945. In 1927 he married Frances Brown of Ohio; they had two children, Helen and Frank.

After his retirement from Harvard in 1956, he sought warmer climes and went to the University of Texas as a Visiting Professor in biology. In 1960 he moved to Tucson, Arizona as he was Visiting Entomologist and Curatorial Assistant at the University of Arizona, where he organized the mollusk collection and continued to collect and study the little known land and freshwater snails of the area. His last paper was on the "Mollusks of the Arid Southwest" with Walter B. Miller, published in 1973.

In 1980 he and his wife Frances moved to Amherst, Massachusetts, to be near their daughter, Dr. Helen Holmes. He died there at the age of 95, on January 12, 1982.

Dr. Bequaert's prolific bibliography (over 250 papers, more than 50 of them on mollusks) attests to his broad background and interests. His work includes medical research on sleeping sickness and schistosomiasis, extensive molluscan studies, particularly of the Achatinidae and Strophochelidae, many works on wasps and other insects, botanical papers, and even a paper on the use of the fauna of putrefaction to determine time of death. He was a member of many scientific societies, president of the American Malacological Union in 1954, and an Honorary Associate in Entomology and Malacology at the Museum of Comparative Zoology from the time of his retirement. Dr. Bequaert, affectionately called Uncle Joe by the many young students then at the MCZ, was available to advise and help at all times. He was an incredible linguist (said he grew up on the streets of Belgium speaking four languages) and was always willing to help translate difficult passages in any of the European languages.

Dr. Bequaert's contribution to malacology and to the Mollusk Department of the MCZ will be appreciated by students for many generations. Memorial contributions to support research in land molluscan systematics may be given to either the Friends of the Department of Mollusks, Museum of Comparative Zoology, Harvard University, Cambridge, MA 02138 or the American Malacological Union, 3706 Rice Boulevard, Houston, Texas 77005.

William J. Clench, *Curator Emeritus*  
Department of Mollusks  
Museum of Comparative Zoology

# *OXYCHILUS DRAPARNALDI* IN IOWA

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## ABSTRACT

*Feral and greenhouse colonies of Oxychilus draparnaldi* (Beck, 1837) in Iowa City, Johnson Co., Iowa constitute the first Iowa record for an introduced land snail. The species has now been reported as feral in 13 states and in greenhouses in 13 states and the District of Columbia. The feral colony was established in or prior to 1966, occupies approximately 2,400 sq. ft. and contains several hundred individuals. Differences in land snail faunas in adjacent areas with and without *O. draparnaldi*, plus feeding experiments, suggests that *O. draparnaldi* reduces local populations of some land snail species.

Records of introduced mollusks in Iowa are extremely rare. Barnhard (1978) lists two slugs and one fresh-water snail; as far as we know this paper constitutes the first record for an introduced land snail in Iowa. In addition, the Iowa City *O. draparnaldi* occurrence is of significance because it is the only Midwest feral colony and because some information as to date of introduction (and hence rate of spread) is available.

In the course of a systematic survey of the land snails of Johnson County, Iowa in 1976-78 a single dead specimen of *O. draparnaldi* was recovered from a drift pile along a fence in the northwest corner of Hickory Hill Park, a city facility in northeastern Iowa City. Subsequent intensive searches for the species resulted in the discovery of living specimens in July 1978 on the west side of a ravine just southwest of the south terminus of St. Clements Street in Iowa City (SE $\frac{1}{4}$  NW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 2, T. 79 N., R. 6 W., Iowa City West 7 $\frac{1}{2}$ ' topographic quadrangle; Fig. 1). Repeated visits to the site were made in March - August 1979 and 1980 to collect *O. draparnaldi* and define the limits of the colony. Litter and drift samples were taken from the colony and adjoining areas to assess the effects, if any, of the introduction. A laboratory colony was maintained for one year to check feeding preferences. Also a visit made to one local greenhouse (Valley Orchards and

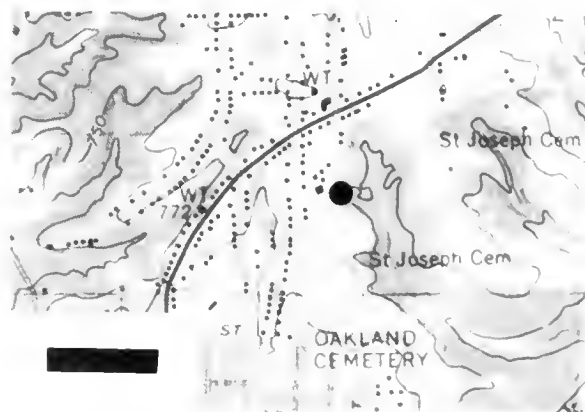


FIG. 1. Portion of Iowa City West 7 $\frac{1}{2}$ ' topographic quadrangle showing location of *Oxychilus draparnaldi* (Beck, 1837) colony (black dot). Scale bar (lower left) length: 0.3 km (approximately 0.2 mi.).

Nursery, Inc., 1302 S. Gilbert) turned up additional *O. draparnaldi*.

Three species of *Oxychilus* (*allarius*, *cellarius* and *draparnaldi*) are common introductions into the United States. Hanna (1966, p. 19) was of the opinion that the three "cannot be separated consistently from shell characters", but Burch (1960, 1962) and Ellis (1969) suggest distinguishing shell features as well as soft body characters enabling relatively easy discrimination of adults of all three. Adult *allarius* are small (6-7 mm diameter), the spire is nearly flat, and the animal is very dark. The larger *cellarius*

(ca. 9 mm diameter) has a more lunate aperture, higher spire, and the animal is pale gray. *O. draparnaldi* is the largest of the three (diameter 12-16.5 mm), has a flattened spire and aperture as in *allarius* but the animal is blue-gray. Our specimens (Fig. 2) fit most readily into *draparnaldi*: mean diameter of the 10 largest specimens is 11.8 mm, the largest (Fig. 2) is 13.2 mm in diameter, and the body is blue-gray. As a further check the Iowa City *Oxychilus* were compared with authenticated European *allarius* and *cellarius* provided by C. R. C. Paul (Liverpool University). Available material (43 specimens) shows little variation in shell, animal color, or spire height.

### Occurrence and Ecology

The feral colony occupies a 200 ft. stretch of

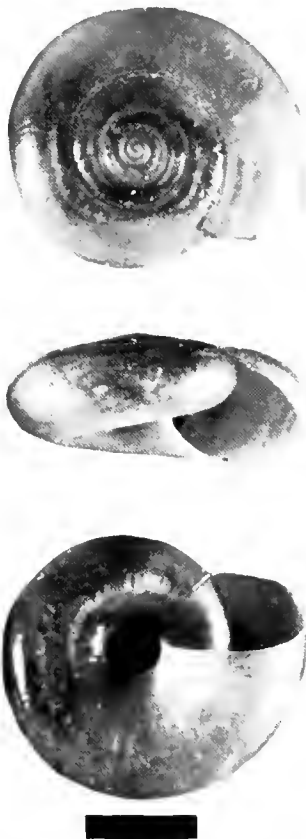


FIG. 2. *Oxychilus draparnaldi* (SUI 49535) from Iowa City, Iowa; respectively top, apertural, and bottom views,  $\times 3$ . Scale bar length is 5 mm. Actual diameter 13.2 mm.

overgrown steep slope (height 10-15 ft.: area about 2400 sq. ft.) on the west side of a small ravine (Fig. 1). Abundance seems to fluctuate yearly even under seemingly identical weather and moisture conditions: our best estimate is that a minimum of 400 individuals are normally present. Abundance also varies widely on the slope with individuals most common under debris near its top. Because the area formerly was a brickyard the present slope configuration is in part artificial. It was still in operation as late as 1935, when the site was collected for Pleistocene (Peoria Loess) land snails (Cameron, 1935). After abandonment the site was largely filled with mixed junk and earth and housing constructed over it. According to the present landowner, filling ceased in 1966. Among the last materials dumped were a considerable quantity of discarded greenhouse stock, including "spoiled" tulip bulbs. It is very likely that the snails were introduced with this material. Following cessation of dumping the slope has been little disturbed, and much of the trash is now overgrown by weeds and fast-growing trees, e.g. elms and cottonwoods. At present, the site is moist and shaded into late summer, but leaf litter and ground cover are sparse. A 2-liter litter sample and hand collecting shows that the site provides adequate habitat for a small land snail fauna of 11 species (Table 1).

Eggs and young have been observed in the

TABLE 1. Comparison of land snail faunas in ecologically similar areas with and without *Oxychilus draparnaldi* (Beck, 1837) at Iowa City, Iowa.

Taxon	with <i>draparnaldi</i>	without <i>draparnaldi</i>
<i>Allogona profunda</i> (Say, 1821)		x
<i>Anguispira alternata</i> (Say, 1816)	x	x
<i>Triodopsis multilineata</i> (Say, 1821)	x	x
<i>Mesodon clausus</i> (Say, 1821)	x	x
<i>Stenotrema fraternum</i> (Say, 1824)		x
<i>Stenotrema barbatum</i> (Clapp, 1904)		x
<i>Catinella avara</i> (Say, 1824)	x	x
<i>Gastrocopta contracta</i> (Say, 1822)	x	x
<i>Gastrocopta pentodon</i> (Say, 1821)	x	x
<i>Hawailia minuscula</i> (Binney, 1840)	x	x
<i>Helicodiscus parallelus</i> (Say, 1821)	x	x
<i>Vertigo tridentata</i> Wolf, 1870		x
<i>Vallonia parvula</i> Sterki, 1893	x	x
<i>Zonitoides arboreus</i> (Say, 1816)	x	x
<i>Petinella indentata</i> (Say, 1823)	x	x

wild from April to August. Captives maintained in a temperature-controlled room, however, laid eggs as early as March. The species is reported to be carnivorous by preference (Ellis, 1969, p. 247), but captive specimens would readily eat a variety of plant and vegetable matter, as well as other land snails. Litter sampling (2 liters) and hand collecting of adjacent dump areas without *draparnaldi* yielded 15 species. Comparison of the two faunas (Table 1) shows considerable overlap, but areas without *draparnaldi* have several additional large species.

Feeding tests, while incomplete, indicate that the Iowa *draparnaldi* are snail carnivores, and that absence (more likely, reduced numbers: the small sample size precludes certainty as to real abundance of the larger species.) of some species in areas with *draparnaldi* is due to selective carnivory, rather than competition for food. Three species available in large numbers, *Triodopsis multilineata* (Say), *Anguispira alternata* (Say), and *Stenotrema fraternum* (Say), were presented to *draparnaldi* alone, with a favorite vegetable food (cucumber slices), in pairs, and all together. *O. draparnaldi* would eat all three snails, but showed a marked preference for *S. fraternum*. *A. alternata* was least favored, being often neglected in favor of cucumbers. *T. multilineata* was eaten frequently, but when paired with *S. fraternum* the latter was preferred. Attempts to induce *O. draparnaldi* to eat smaller species (*Z. arboreus* and *G. contracta*) were unsuccessful. In summary, Iowa *O. draparnaldi* can subsist on a variety of plant and animal foods, and shows a moderate preference for animal matter, particularly relishing *S. fraternum*. It seems probable that absence (or rarity) of some large native species from areas inhabited by *O. draparnaldi* is due to predation by the introduced snail.

Because of the proximity of a city park, the Iowa City colony will probably persist. Although some intervening areas are presently unsuitable for snails, maintenance of Hickory Hill Park in a relatively undeveloped state makes available a large area suitable for colonization. The nearest suitable habitat is 0.3 mi. (0.3 km) southeast in the Iowa River valley (Fig. 1), and finds of occasional *O. draparnaldi* in the intervening stretch make

continued spread highly probable. The colony is within 0.7 mi. (1.1 km) of the Iowa River valley: the ravine in which it is situated drains into Ralston Creek 0.6 mi. (0.9 km) down valley. Though both waterways are locally heavily urbanized, both will provide adequate habitat for *O. draparnaldi*. If the present rate of spread (i.e. 200 ft. in 14 years: 15 ft/yr.) is now maintained), *O. draparnaldi* would reach Ralston Creek in 211 years and would require around 1000 years to reach the Iowa River via Ralston Creek, a distance of approximately 6 mi. (13.2 km). These figures are probably conservative: to cite a well-known example, 50 years after the deliberate introduction of *Triodopsis fosteri* (Baker) into Burlington, New Jersey by W. G. Binney, the species had progressed a minimum of 8 miles to Plum Point, New Jersey via the Delaware River valley (Pilsbry, 1940), a rate of 845 ft/yr.

### U. S. Distribution

Counting the Iowa records, introductions of *O. draparnaldi* are reported from 13 states as feral colonies and 13 states and the District of Columbia as greenhouse colonies (Table 2); the scattered literature is well summarized in Pilsbry (1946), Hanna (1966) and Dundee (1974). Judging from the number of greenhouse citations in states which have been surveyed in detail (e.g. New York, 25 counties: Wurzing, 1975, p. 37), many more feral colonies probably exist, and the potential for continued accidental introduction is great. The Iowa colony is significant in that it is the first Midwest feral colony to be reported: others are concentrated on the east and west coasts or in long-settled areas of the U.S. (Fig. 3). Burch (1960, p. 25-26) reports the original distribution of *O. draparnaldi* to include much of Europe, the Orkney and Shetland Islands, the Outer Hebrides, Asia Minor, North Africa, and Madeira. Both U. S. and foreign distributions suggest a synanthromorph with broad environmental tolerances making much of the continental U. S. potential habitat. The species does not appear to be a major agricultural pest. The greatest potential for ecological disruption seems to be in its possible tendency to prey on native snails, combined with its poten-

TABLE 2. *U. S. occurrences of Oxychilus draparnaldi* (Beck, 1837).

State	Type	
	Feral	Greenhouse
California	X	X
Colorado		X
District of Columbia		X
Georgia	X	
Illinois		X
Iowa	X	X
Maryland	X	X
Massachusetts	X	X
Michigan		X
New Jersey	X	X
New York	X	X
Ohio		X
Oregon	X	X
Pennsylvania	X	X
South Carolina	X	
Virginia	X	
Washington	X	X
West Virginia	X	

tially wide distribution. It is somewhat analogous to the native *Haplotrema concavum* in its environmental and feeding preferences; thus the possibility of its being directly competitive with the latter should be investigated.

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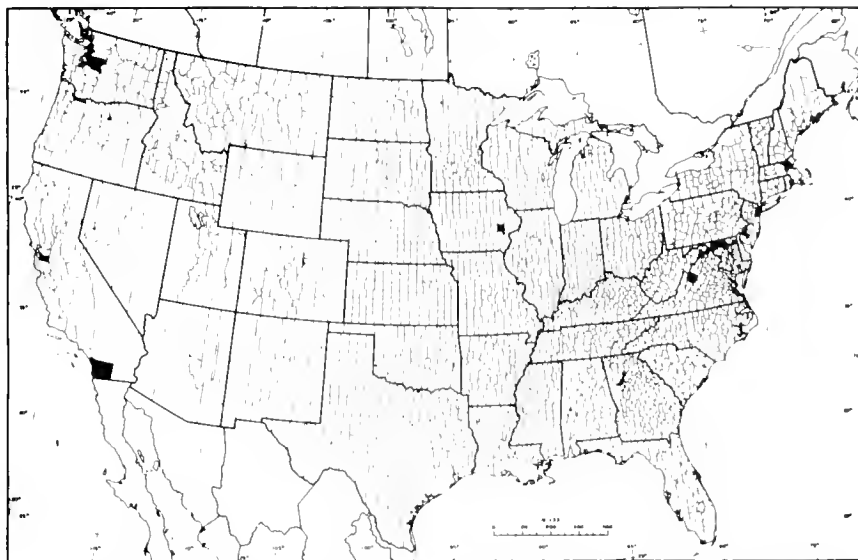


FIG. 3. County map of U. S. showing localities with feral *Oxychilus draparnaldi* (Beck, 1837). Note concentration on west and east coasts.

*ISCHNOCHITON DILATOSCUPTUS*, A NEW SPECIES FROM FLORIDA  
(POLYPLACOPHORA: ISCHNOCHITONIDAE)

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My friend, Mr. Richard A. Van Belle, Sint-Niklaas, Belgium, showed to me two *Ischnochiton* specimens which he had received from collectors in Florida. One of them proved to be correctly identified by Van Belle as *Ischnochiton* (*I.*) *pseudoringatus* Kaas, 1972. It is a fine, 7-valved, dried and flattened specimen, collected by Mr. A. Crovo at Long Reef, off Elliott Key, Florida, 18th August 1968, in the base of a "sea-fan", and sent to Van Belle by Mr. D. Steinke. The specimen, measuring 3.2 mm long, 1.8 mm wide, 0.6 mm high, is no. 2601 in the collection of Van Belle. In all respects it is identical to the holotype from Curaçao, and the single paratype from Aruba, Lesser Antilles.

Seven-valved specimens of Polyplacophora are rather rare, but well-known. *Acanthochitonu crinita* (Pennant, 1777), and the holotype of *Callochiton septemvalvis* (Montagu, 1803) are abnormally seven-valved (*vide* Kaas, 1978).

The other specimen could not be identified as it differs from all known species of *Ischnochiton*. It was collected by Mr. R. Lyles in 1968, off Fort Lauderdale Beach, Florida, in a depth of 12 m. Although only one specimen was procured, its characteristics are decisive enough to attach a new name to it:

*Ischnochiton dilatoscultus* n. sp.  
(Figs. 1-9)

**Material:** 1 specimen, dry. Off Fort Lauderdale Beach, Florida, U.S.A., 12 m. R. Lyles, leg., now in the Rijks Museum van Natuurlijke Historie, Leiden, Holotype 55382.

**Diagnosis:** Animal elongate oval, moderately elevated, hardly carinated, angle of divergence  $\pm 110^\circ$ , the valves only slightly beaked, side slopes a little convex (Fig. 1). Head valve semi-circular, uniformly granulated, the anterior margin not decorated by a row of large

granules. Total length of animal: 14.5 mm; width 8.5 mm.

Intermediate valves (Fig. 2) not sharply divided into central and lateral areas as the latter are not raised, only marked by a sculptural division. The dorsal part of the central area is irregularly granulose, more or less reticulate. Towards the pleurae the granules rapidly increase in size, forming curved longitudinal chains, strongly converging close to the division between central and longitudinal areas, where they meet the chains of granules sculpturing these parts of the valves, which are diverging towards the anterior and side margins, thus giving the valves a fan-like, or feather-like, appearance. On the lateral areas the granules make the sutures dentate.

Mucro of the posterior valve subcentral, not very prominent, the back slope slightly concave. Antemucronal area sculptured like the central areas of the intermediate valves, postmucronal area like the head valve. Both areas are divided by a rib formed by larger granules.

The articulamentum is well-developed, porcelaneous, somewhat transparent; the color of the tegmentum showing through; apophyses evenly rounded, separated by a wide, bay-like sinus; insertion plates smooth, with 8 inequidistant slits in the anterior valve; 1-1 slits in the intermediate valves, and 11 slits in the posterior valve; the slit-rays well-marked, the eaves solid.

The tegmentum is cream-colored, with irregular light greenish gray spots, especially towards the side margins of the valves.

Girdle dorsally clothed with imbricating scales,  $66\ \mu$  wide,  $48\ \mu$  high, the base narrowly diamond-shaped; the strongly convex dorsal side with 8-10 strong, narrow riblets, converging towards the broadly rounded top of the scale; interstices twice as wide as the ribs (Fig.



FIGS. 1-9. *Ischnochiton dilatatosculptus* new species. 1, Off Fort Lauderdale Beach, Florida. Holotype (12 mm); 2, Left half of valve VI ( $\times 20$ ); 3, Dorsal girdle scale,  $66\ \mu$  broad; 4, Ventral girdle scales (the largest  $48\ \mu \times 16\ \mu$ ); 5, Major lateral radula tooth (side view); 6, Cusp of major lateral radula tooth; 7, Central tooth of radula; 8, First lateral tooth of radula; 9, Minor lateral tooth.

3). There is no marginal fringe. Ventral side of girdle paved with radiating rows of rectangular flat scales, about  $48 \times 16\ \mu$  (Fig. 4).

Central tooth of the radula (Fig. 7) twice as long as wide, reversed pear-shaped at the base, distally sharply pointed, the second (major) lateral tooth with a strongly developed tridentate cusp (Figs. 5, 6) and an interior projection just below the cusp. Minor lateral tooth strongly

curved, gradually widening distally, ending in a blunt point, non-cuspidate (Fig. 9).

*Discussion:* *Ischnochiton* (*I.*) *dilatatosculptus* undoubtedly belongs to the group of *I. (I.) striolatus* (Gray, 1828), *erythronotus* (C. B. Adams, 1845), and *papillosus* (C. B. Adams, 1848), well known from the Caribbean region (including Florida and Bermuda), from which it markedly differs in its quite peculiar sculpture, the dif-

ferently, more sparsely ribbed dorsal girdle scales, and the differently shaped central radular tooth.

It is to be hoped that more specimens will turn up in due course, although I have the impression that it is rather rare in this well-investigated area.

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## A NEW TROPICAL EASTERN PACIFIC OVULIDAE (GASTROPODA): *XANDAROVULA HAMMESI*

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In a recent review of the Ovulidae, Cate (1973) listed 7 species from the Panamic province (tropical west America). Since then, although more than 25 additional new taxa of ovulids have been proposed from Indo-Pacific and Caribbean waters (e.g., Azuma, 1972; Cate, 1974b, 1975, 1976a, and 1978; and Petuch, 1979), only one new species has been named from the Panamic region (Cate, 1976b). Emerson and Old (1965) had previously reported the Galapagan occurrence of *Pseudocypraea adamsonii*, an Indo-Pacific ovulid. To these tropical eastern Pacific ovulid species we add the following: 2 species from Panama, one known only from the type locality and the other a widely ranging taxon in the western Pacific:

*Xandarovula hammesi*  
Bertsch & Bibbey, sp. nov.  
(Figs. 1-6)

*Description:* Thin, white glossy shell, quite large for the genus; ovalish, with both ends pointed; bulbous in the middle; adapical terminal protrudes strongly, completely on right-half of shell, distinctly notched on the left side of the bulbous body; adapical terminal much

more gently narrowing along the left side; smooth except for extremely fine longitudinal growth striae, and faint, fine transverse line more prominent terminally and on the columella; outer lip evenly rounded, circular rather than oval; no lip callus; apertural opening comprises nearly 1/2 the total area of the ventral side; aperture terminals open slightly to the side adapically, but straight abapically (anteriorly); anterior columellar region thin and narrow, forming a fragile edge to the anterior gutter-shaped siphonal canal; posterior axis delicately tortuous, twisting a full 180° from its proximal juncture with the body whorl to its distal termination.

### Measurements:

	Length	Width
Holotype,	37 mm	19 mm (Figs. 1 and 2)
Paratype,	31 mm	14 mm (Figs. 3 and 4)
(Hammes' collection)	33 mm	17 mm (Figs. 5 and 6)

*Type locality:* All three specimens examined were collected in shrimp nets from about 1000 feet, off Cebaco Island (approx. 7°30'N; 81°30'W), Pacific coast of Panama, approximately in September of 1979. Holotype: San Diego Natural History Museum, Marine Inver-





FIGS. 1-4. *Xandarovula hammesi*. 1 and 2, Holotype (SDNHM Marine Invertebrates T.S. 513), 37 mm in length. 3 and 4, Paratype (SDNHM Marine Invertebrates T.S. 517). (Photos by Bertsch)



FIGS. 5 and 6. *Xandarovula hammesi* n. sp. Paratype in the Hammes' collection. Length: 33 mm. (Photos by Bertsch)

tebrates, Type Series 513. Paratype: S.D.N.H.M., Type Series 517.

**Discussion:** This new species is separated from the other 5 known species of *Xandarovula* by geographic location (*X. patula* occurs in European waters, and the other 4 species are western Pacific, from Japan to Australia) and morphology. *Xandarovula hammesi* has an evenly rounded outer lip, but the lip flares adapically in *X. pagoda* Cate, 1973, and flares (is broader, wider) adapically in *X. patula* (Pennant, 1777). *Xandarovula xanthochila* (Kuroda, 1928) and *X. formosana* (Azuma, 1972) both

have a slight callus and sulphur yellow coloration along the margin of the outer lip; by contrast, the outer lip of *X. hammesi* has no thickening and is the same white as the rest of the shell. This new species most resembles *X. figgisae* Cate, 1973, but can be immediately distinguished by the shape of the adapical (posterior) terminal. In *X. figgisae* the columellar portion of the terminal extension is relatively broad and short (width greater than 1/2 the length). Comparative illustrations of European and western Pacific *Xandarovula* can be found in Cate (1973: figs. 66 to 71) and Azuma (1972: figs. 2 and 3; radula, fig. 7) and 1976: plt. 1, figs. 14 and 15).

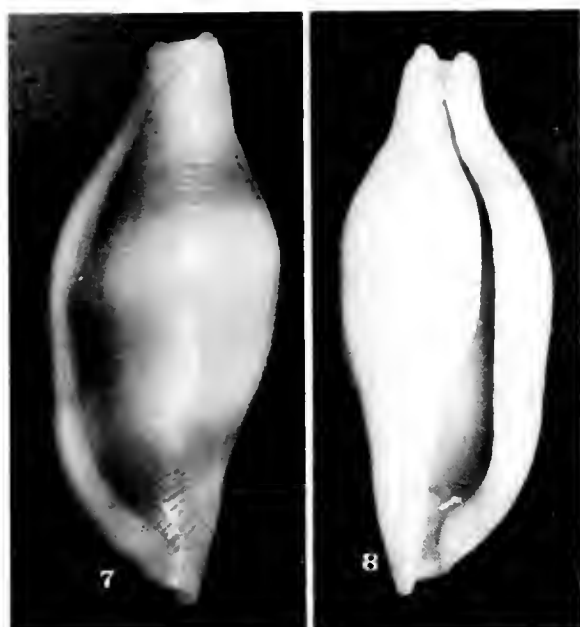
**Etymology:** This new species honors Mr. Terry Hammes, of Panama.

*Phenacovolva brevirostris* (Schumacher, 1817)  
(Figs. 7-8)

**Description:** Smooth pale-apricot shell, with 3 transverse brownish bands; spindle-shaped; thick callus on outer lip, orange-colored, straight anteriorly, angles sharply at each end; funiculum faintly crenate.

**Measurement:** 20 mm × 9 mm; in the collection of the American Museum of Natural History, Department of Invertebrates, AMNH 198612.

**Locality:** This specimen was live-collected near Los Zurroneles, west Panama, by Royce E. Hubert, in 1979. Mr. William E. Old, Jr., first



FIGS. 7 and 8. *Phenacovolva brevirostris* from western Panama (AMNH 198612). (Photos by Barbara Myers)

identified and recognized the significance of this specimen.

**Discussion:** Two recent papers have summarized the known Indo-Pacific gastropod mollusks that occur in tropical west America (Emerson, 1978; Bertsch, 1979). The related family Cypraeidae has about 10 Indo-Pacific species in the Panamic province, but this is only the second ovulid with pan-Pacific distribution. Previous records of the present species include the east Asian mainland, the Japanese Ryukyus, Philippine and Cook Islands, Celebes-Sulu Sea (Cate, 1969:364-365), Queensland and Sydney, Australia (Allan, 1956:132) and Hawaii (Kay, 1979:204). This, however, is the first record of the species from the Pacific coast of the Americas.

Detailed comparison of internal and external (shell) anatomy will be necessary to determine the relationship between *Phenacovolva brevirostris* and *P. lemoreae* Cardin & Walls, 1980.

#### ACKNOWLEDGMENTS

We thank Barbara Myers (SDNHM) for the

photographs; Dr. William K. Emerson and William E. Old, Jr. (AMNH) for advice and the loan of the *Phenacovolva* specimen, and Terry Hammes for allowing us to examine his *Xandarovula* specimens.

TABLE 1. *Species of Ovulidae in the eastern Pacific. Distribution Key: P signifies a Panamic species (tropical west America); C a Californian species, and IP indicates Indo-Pacific distribution. Generic usages after Cate (1974a), McLean (1978), and Schilder and Schilder (1971).*

<i>Cymborula</i> Cate, 1973
<i>Cymborula bratcheriae</i> (Cate, 1973) P
<i>Cyphoma</i> Röding, 1798
<i>Cyphoma emarginatum</i> (Sowerby, 1830) P
<i>Delonovolva</i> Cate, 1973
<i>Delonovolva aequalis</i> (Sowerby, 1832) P
<i>Delonovolva aequalis vidleri</i> (Sowerby, 1881) C
<i>Delonovolva macleani</i> Cate, 1976 P
<i>Jenneria</i> Jousseaume, 1884
<i>Jenneria pustulata</i> (Lightfoot, 1786) P
<i>Neosimnia</i> Fischer, 1884
<i>Neosimnia arena arena</i> (Sowerby, 1832) P
<i>Pedicularia</i> Swainson, 1840
<i>Pedicularia californica</i> Newcomb, 1864 C
<i>Phenacovolva</i> Iredale, 1930
<i>Phenacovolva brevirostris</i> (Schumacher, 1817) P & IP
<i>Pseudocypraea</i> Schilder, 1927
<i>Pseudocypraea adamsonii</i> (Sowerby, 1832) P & IP
<i>Simnialena</i> Cate, 1973
<i>Simnialena inflexa</i> (Sowerby, 1832) P
<i>Simnialena rufa</i> (Sowerby, 1832) P
<i>Spiculata</i> Cate, 1973
<i>Spiculata barbarensis</i> (Dall, 1892) C
<i>Spiculata loebbeckeana</i> (Weinkauff, 1881) C
<i>Subsimnia</i> Cate, 1973
<i>Subsimnia bellamaris</i> (Berry, 1946) C
<i>Xandarovula</i> Cate, 1973
<i>Xandarovula hammesi</i> Bertsch & Bibbey sp. nov. P

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- (Contribution number 2 from the Escuela de Ciencias Marinas, U.A.B.C., Ensenada, B.C., Mexico.)

## A NEW *FAVORINUS* (NUDIBRANCHIA: AEOLIDOIDEA) FROM THE CANARY ISLANDS

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### ABSTRACT

*Favorinus vitreus*, a new nudibranch is described from the Canary Islands with a discussion of other Atlantic species.

In July 1980, among material collected from Tenerife, during a trip supported by the Junta de Canarias and La Laguna University, we found 40 species of Ascoglossa and Nudibranchia; of the latter, I collected two specimens of a small *Favorinus* with two white swellings in the rhinophores which is here described as a new species.

*Favorinus vitreus* n. sp.  
(Figs. 1-3)

*Type locality:* Los Cristianos beach (26°00'N; 16°30'W), Tenerife, Canary Islands, 23 July 1980, two specimens found on the brown algae (*Sargassum* sp. and *Cystoseira* sp.) with small polyzoans and spaws of an undetermined Polyceridae.

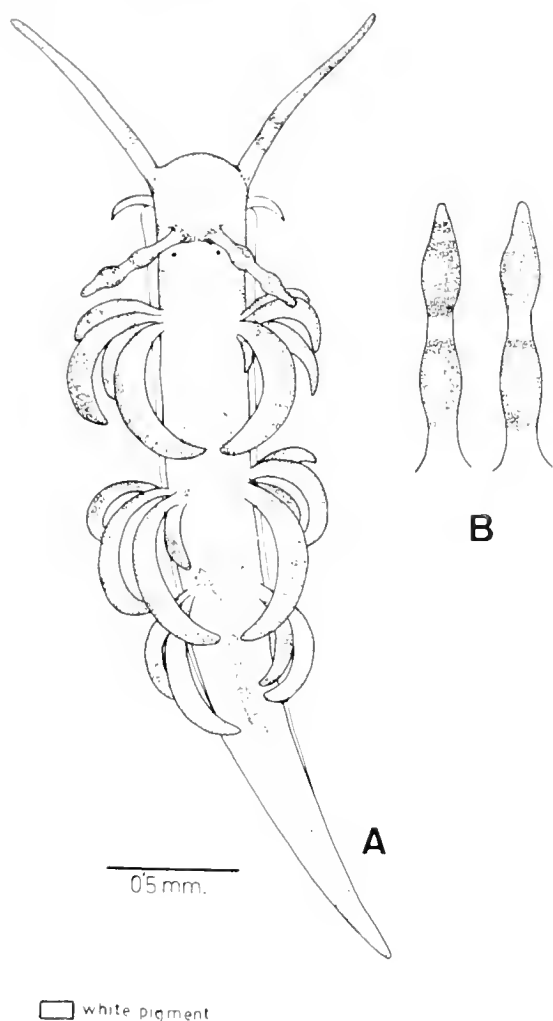


FIG. 1. *Favorinus vitreus* n. sp.: A, dorsal view of living animal; B, rhinophores.

**Holotype:** I deposited in the Museum national d'Histoire Naturelle, Paris.

**Description:** The two living animals are 3 mm in length; oral tentacles, elongate, 1 mm; rhinophores 0.5 mm; foot 0.3 mm; and cerata up to 0.7 mm. Animals translucent white (glassy) with the head, rhinophores, oral tentacles and cerata white opaque. Body translucent, with an opaque white marking on both specimens. This broad band is discontinuous in one specimen (fig. 1,A) and continuous in the other. Rhinophores have two small and two large white bulbs (fig.

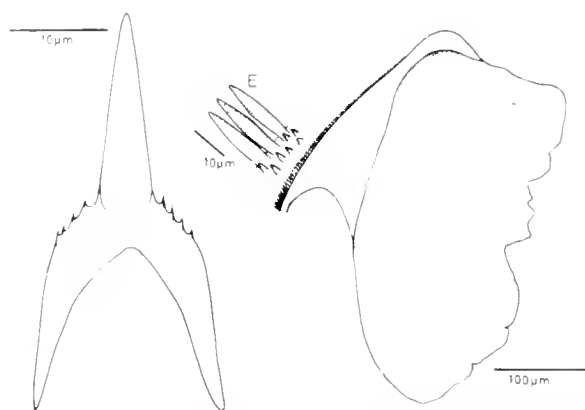


FIG. 2. *Favorinus vitreus* n. sp. Left: radular tooth; right: jaw.

1,B). Cerata arranged in arches in the first and second group; the third and fourth groups arranged in rows. The fifth group is a solitary ceras. The second arch is nearly a row. The number of cerata per a arch or row in the 3-mm-long holotype are as follows: left side: 6, 5, 3, 2, 1; right side: 6, 4, 3, 2, 1.

We have not observed any cnidosacs in the cerata. Liver branches in the cerata not visible in the living animal, as the white surface of the cerata is opaque. Liver ducts in body completely transparent. Foot transparent, with two translucent anterior corners. Cardiac area not prominent.

The animal did not autotomize its cerata when it was poked with tweezers, nor when narcotized with magnesium chloride. There is a dorsal indentation to the jaw (fig. 2) the masticatory border is not complete but has several irregular rows of pointed teeth (fig. 2,E). The radula has 17 teeth, 30–35 μm in height. Each tooth has a strong central cusp with four or five acutely pointed denticles on each side (fig. 2). The penis is unarmed.

**Derivation of name:** This species is called *F. vitreus*, because of the transparency of its body (vitreo = glassy).

**Discussion:** The Atlantic species of *Favorinus* can be artificially divided into two groups according to the color of the rhinophores:

a) **animals with brown rhinophores.**

*F. branchialis* (Müller) from Northern Europe

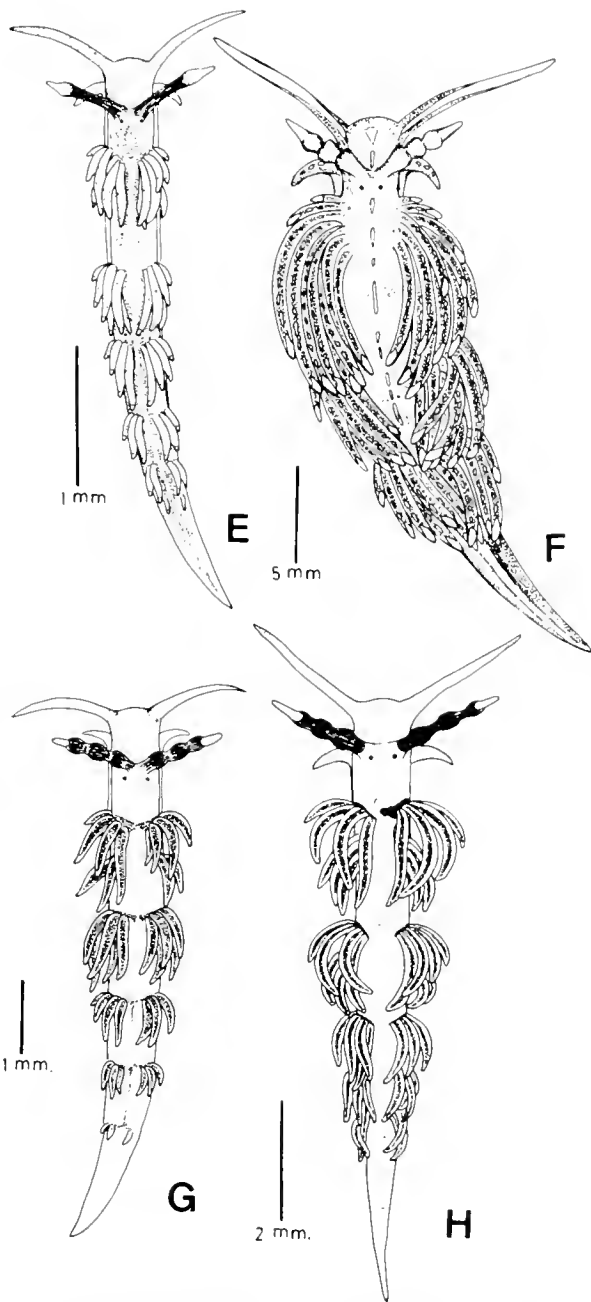


FIG. 3. Atlantic species of *Favorinus*. E, *F. branchialis*, animal from Asturias (northern of Spain); F, *F. blianus*, animal from Galicia (northern Spain); G, *F. auritulus*, drawing adapted from Marcus (1980); H, *F. ghanensis*, drawing adapted from Edmunds (1968).

and the Mediterranean (Thompson & Brown, 1976), Morocco (Pruvot-Fol, 1953) and Cape

Verde Islands (Eliot, 1906 as *F. carneus*), found also in the Canary Islands (personal observation); *F. ghanensis* Edmunds, from Ghana (Edmunds, 1968; 1974); and *F. auritulus* Marcus, from the tropical west Atlantic (Edmunds, 1964; Marcus, 1955; Marcus & Marcus, 1963, 1970; Marcus & Hughes, 1974 and Edmunds & Marcus, 1977) possess brown rhinophores.

b) animals with white rhinophores.

*F. blianus* Lemche & Thompson (fig. 3,F), from Northern Europe (British Isles and Scandinavia) (Lemche & Thompson, 1974; Hunnam & Brown, 1975), found also in the northern Spain (Ortea & Urgorri, 1981); and *F. vitreus* n. sp. from Tenerife possess white rhinophores. A *Favorinus* sp. which possibly belongs to this second group, has been reported by Eliot (1906, p. 159) from the Cape Verde Islands.

*F. blianus* differs from *F. vitreus* by having voluminous bulbs on the rhinophores and by the distribution of the white opaque pigment in its body, with discontinuous patches on the cerata and anterior corners of the foot. It also reaches a larger size, and its radular teeth lack denticles on the sides of the large central cusp.

Among the species with brown rhinophores, *F. ghanensis* seems to be a clearly defined species due to its penial stylet and because it feeds upon bryozoans, an exceptional diet for an eolid nudibranch (Edmunds, 1974). However, *F. branchialis* also feeds upon Bryozoa when the edible spawn of opisthobranchs is scarce, as we have been able to observe in Asturias, northern Spain, where it is frequently collected during the winter on *Bugula fastigiata* and *B. fulva*. When *F. branchialis* eats *Bugula*, the color of the liver in its cerata is violet-brown, as in those of *F. ghanensis*. Three rhinophoral bulbs may also be rarely present in *F. branchialis*, so that, the differences between these species is limited to the existence of the penial stylet in *F. ghanensis* and small details of coloration (few white dots on the body of *F. ghanensis*, a dorsal band in *F. branchialis*).

The difference between *F. branchialis* and *F. auritulus* is mainly in the 3 bulbs usually present in *F. auritulus*. The spawn, which may help to separate species, is only known from *F. branchialis*, and it consists in a regular and con-

centric spiral cord (Lovén, 1841; Alder & Hancock, 1845-55; Meyer & Möbius, 1865 and Vayssière, 1888) with eggs of 65-70  $\mu\text{m}$  in diameter in northern Spain (personal observation), while Haefelfinger (1962) observed eggs of 45-60  $\mu\text{m}$  from a spawn from Villefranche-sur-Mer. Vayssière (1888) noted eggs of 50  $\mu\text{m}$  from the Mediterranean and Rasmussen (1951) of 70  $\mu\text{m}$  from Copenhagen (Denmark).

### RESUMEN

Descripción de una nueva especie, *Favorinus vitreus*, recolectada en Tenerife, islas Canarias, caracterizada por tener rinóforos blancos y con dos bulbos, tentáculos orales largos (1/3 del cuerpo) y ceratas, pigmentados uniformemente de blanco en la superficie.

### ACKNOWLEDGMENTS

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## THE CHANGING OHIO RIVER NAIAD FAUNA: A COMPARISON OF EARLY INDIAN MIDDENS WITH TODAY

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### ABSTRACT

*In prehistoric times the upper Ohio River supported a population of at least 32 species of freshwater mussels. By the turn of the Twentieth Century at least seven species had been extirpated from the river. At the present time there are only 13 of the original 32 species still occasionally found in the river. The river habitat has been modified by man and at least 15 species new to the river have moved in. While the total number of individuals currently living in the river is only a small percentage of what it was prehistorically, the total number of species has only changed from 32 to 28.*

A survey of the freshwater naiads of the upper Ohio River was conducted by a team of biologists from Marshall University during the summer of 1979 (Taylor, 1980). This work was conducted with support by the United States Army Corps of Engineers, Huntington/Pittsburgh Districts. As a result of the survey, it was found that today there exists a fairly diverse naiad faunal assemblage (composed of at least 27 resident species) in this part of the river. Upon comparing these data with those presented by Ortmann (1921) it is immediately obvious that radical changes in the faunal make-up have taken place since the turn of the century.

Within the past 200 years man has severely modified the river through industrial and human pollution, damming and dredging. The Ohio River is a much different river from the pristine Ohio that freely flowed for eons of time prior to the coming of European man. Native Americans, in apparently large numbers, had lived in harmony with the river utilizing its resources in moderation and adding nothing which would seriously harm or modify the river.

The habit by some American Indians of disposing of their wastes in garbage pits has provided contemporary paleoecologists with a very useful tool through which much can be learned about the lifestyle of these primitive people. A major component of most midden piles, along

this portion of the river, is a large amount of well-preserved freshwater mussel shell material. Early man used the mussel meat as a food at least part of the year, and the shells were ground and used as a tempering agent in the manufacture of clay pottery. Relatively few of the shells were incorporated into pottery; the majority was discarded after the flesh had been removed for human consumption. These shells remain so well preserved that even today, using conchological characters only, they can be readily identified to species level.

### Method

The initial phase of this study was a boat survey of the freshwater mussels which presently (1979) inhabit a 340-mile long portion of the Ohio River between Pittsburgh, Pennsylvania and Greenup, Kentucky. Collecting techniques included brailling, handpicking in the shallows and collecting on the banks where muskrats had disposed of empty shells after eating the flesh. The shells were then identified, cataloged and accessioned into the Marshall University Malacological collections.

Literature records from Parodiz (1953) and Stansbery (1977) provided information on two sites. We report the results, in this paper, of the excavation of three additional sites. Figure 1

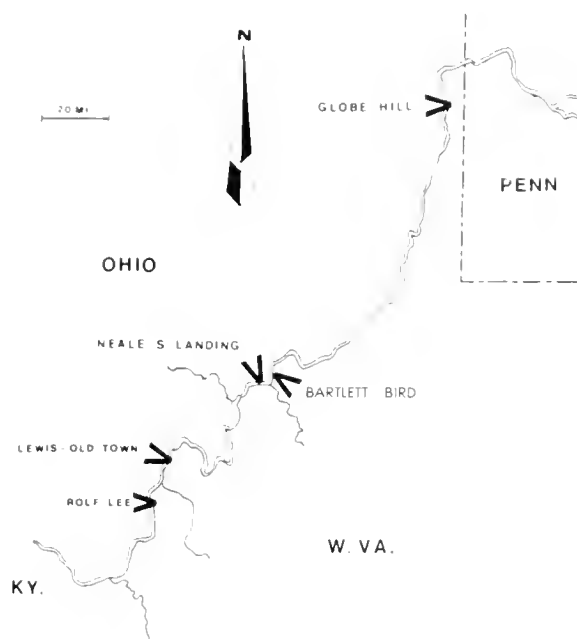


FIG. 1. Map of the upper Ohio River showing the approximate location of the archeological sites bearing freshwater naivids.

shows the respective archeological sites, while Table 1 gives additional pertinent information. In addition, the published works of Ortmann (1921) and Rhoads (1899), in conjunction with Carnegie Museum records, were used to determine the status of freshwater mussel populations in the upper Ohio River at the turn of this century.

## Results and Discussion

By combining the data derived from all five archeological studies we were able to produce a composite list which shows that within the last 2,000-or-so years at least 32 species of mussels have lived in this part of the Ohio. By the middle 1800's the radical modification of the Ohio River (required for navigation) had begun, and in addition the large industrial complexes and cities along the Ohio began using the river as a waste disposal system. Because of these alterations Ortmann in 1921 was unable to find seven of the 32 species used by the Indians. Those species which were present in goodly numbers in earlier times, but which were extinct in the river by 1900, are listed in Table 2.

The misuse and modification of the river has continued until the present. Between the years of 1900 and 1980 an additional 12 species have been eliminated (Table 3). Of the original 32 species of mussels which inhabited the Ohio River in large numbers as recently as the 1600's, only 13 were found in the 1979 survey. Nineteen species had been extirpated from the entire upper Ohio over a relatively short period of time.

The picture is not, however, as bleak as it may seem. Although the river is still far from being clean, steps have been taken by state and federal agencies that will insure a continued improvement in water quality and thus improve the habitat. The fact remains that while water quality may someday improve to an acceptable

Table 1. Additional information on the archeological sites.

Site Name	Investigator	Excavation Date	Habitation Date	No. Species Identified
Globe Hill	Paradiz	1953	2000 B.C.	7
Neale's Landing	Stansbery	1977	1600 A.D.	24
Bartlett Bird	Leider and Spurlock	1979-80	1350 A.D.	23
Lewis Old Town	Leider and Spurlock	1979-80	1600 A.D.	28
Rolf Lee	Leider	1980	1300 A.D.	26
				32 species



TABLE 2. *Mussel species which became extinct in the Ohio River between 1600 and 1920.*


---

<i>Plethobasus cicatricosus</i> (Say, 1829)
<i>Pleurobema clava</i> (Lam., 1819)
<i>Pleurobema sintoria</i> (Raf., 1820)
<i>Pleurobema rubrum</i> (Raf., 1820) (= <i>plenum</i> )
<i>Epioblasma fleruosa</i> (Raf., 1820)
<i>Epioblasma torulosa</i> (Raf., 1820)
<i>Ptychobranhus fasciolaris</i> (Raf., 1820)

---

TABLE 3. *Species extirpated from the Ohio River between 1920 and 1980.*


---

<i>Plethobasus striatus</i> (Raf., 1820)
<i>Plethobasus cyphus</i> (Raf., 1820)
<i>Quadrula cylindrica</i> (Say, 1817)
<i>Elliptio dilatata</i> (Raf., 1820)
<i>Cyprogenia stegaria</i> (Raf., 1820)
<i>Actinonaias l. carinata</i> (Barnes, 1823)
<i>Obovaria retusa</i> (Lam., 1819)
<i>Obovaria subrotunda</i> (Raf., 1820)
<i>Ligumia recta</i> (Lam., 1819)
<i>Lampsilis abrupta</i> (Say, 1831) (= <i>orbiculata</i> )
<i>Lampsilis ovata</i> (Say, 1817)
<i>Obovaria olivaria</i> (Raf., 1820)

---

TABLE 4. *Mussel species which have established residence in the upper Ohio River in historical times.*


---

<i>Anodonta imbecillus</i> Say, 1829
<i>Anodonta g. grandis</i> Say, 1829
<i>Anodonta g. corpulenta</i> Cooper, 1834
<i>Strophitus u. undulatus</i> (Say, 1817)
<i>Lasmigona costata</i> (Raf., 1820)
<i>Lasmigona complanata</i> (Barnes, 1823)
<i>Lasmigona compressa</i> (Lea, 1829)
<i>Quadrula quadrula</i> (Raf., 1820)
<i>Fusconaia flava</i> (Raf., 1820)
<i>Unio merus tetralasmus</i> (Say, 1830)
<i>Leptodea fragilis</i> (Raf., 1820)
<i>Potamilus alatus</i> (Say, 1817)
<i>Potamilus ohioensis</i> (Raf., 1820)
<i>Toxolasma parvus</i> (Barnes, 1823)
<i>Villosa l. iris</i> (Lea, 1829)

---

others. There is a totally new mussel fauna presently found in the Ohio River. In addition to the 13 remaining species of the original fauna, there are 15 species which have established residence within the last century (Table 4). None of these species has been found in the archeological material from the five test sites. While none of these species is presently found in commercially harvestable quantities, most are found in goodly numbers throughout the entire upper Ohio. One noteworthy example is *Quadrula quadrula*. Rhoads (1899) stated that this species did not extend above Cincinnati, but it is presently found in many large beds throughout the study area.

#### ACKNOWLEDGMENTS

We wish to express our appreciation to the U.S. Army Corps of Engineers, Huntington/Pittsburgh Districts, for support of parts of this study. As always, many thanks are due Dr. David H. Stansbery of the Ohio State University Museum of Zoology for his help in identification and/or confirmation of some of our specimens.

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level the river is irreversibly altered as a result of damming. The river exists today as a series of impoundments rather than a free-flowing river.

As the river habitat became intolerable for some naiad species, it became acceptable for

FRESHWATER MUSSELS (UNIONIDAE) OF BIG MOCCASIN CREEK,  
SOUTHWESTERN VIRGINIA

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## ABSTRACT

*A survey of the mussel fauna of Big Moccasin Creek, an 88-km tributary of the North Fork of the Holston River, was conducted during 1979 and 1980. Eight species were collected, in comparison with fourteen taken during an earlier survey in 1915. The endangered fine-rayed pigtoe, Fusconaia cuneolus, has seemingly been extirpated from this stream.*

The Upper Tennessee River drainage historically contained one of the most diverse naiad faunas in the world. Ortmann's (1918) summary of early mussel surveys recorded an abundant and diverse fauna in major headwater tributaries, which included the Clinch, Powell, and Holston Rivers, Virginia. Recent mussel surveys in these rivers (Stansbery 1972; Hill et al. 1974; Stansbery and Clench 1973, 1974; Bates and Dennis 1978; Ahlstedt and Brown 1979; Neves et al. 1980) have demonstrated a significant decline in species diversity and abundance, due largely to habitat alteration and water quality degradation.

The loss of mussel populations in Virginia has been greatest in the North Fork of the Holston River between Saltville and the Virginia-Tennessee state line (120 km of river). The 38 mussel species that once occurred in this section of river (Ortmann 1918) were eradicated by chemical waste inputs from a now defunct chem-

ical plant at Saltville. Big Moccasin Creek (BMC), the largest tributary of the North Fork, was not affected by these chemical wastes. Ortmann (1918) reported 14 mussel species from two sites on BMC, including the now endangered fine-rayed pigtoe, *Fusconaia cuneolus*. Because the naiad fauna of this creek had not been examined for more than 60 years, we surveyed several sites on BMC during 1979 and 1980 to determine what changes in species composition had taken place and whether *F. cuneolus* still occurred in the stream.

## Study Area

Big Moccasin Creek, an 88-km tributary of the North Fork Holston River, flows through Russell and Scott counties in southwestern Virginia (Fig. 1). The creek has a mean discharge of 0.37 m<sup>3</sup>/s, mean gradient of 3 m/km and drains 247 km<sup>2</sup> of Valley and Ridge Province, which is characterized by sedimentary strata of limestones, dolomites, shales, and sandstones. Roughly 58% of the watershed is forested; most of the remaining land is used for grazing of livestock and cultivation of tobacco. Upstream water chemistry measurements during low flow in October 1979 were as follows: temperature,

<sup>1</sup>The Virginia Unit is jointly supported by the U.S. Fish and Wildlife Service, the Virginia Commission of Game and Inland Fisheries, the Virginia Polytechnic Institute and State University.

<sup>2</sup>The Florida Unit is jointly supported by the U.S. Fish and Wildlife Service, the Florida Game and Freshwater Fish Commission, and the University of Florida.

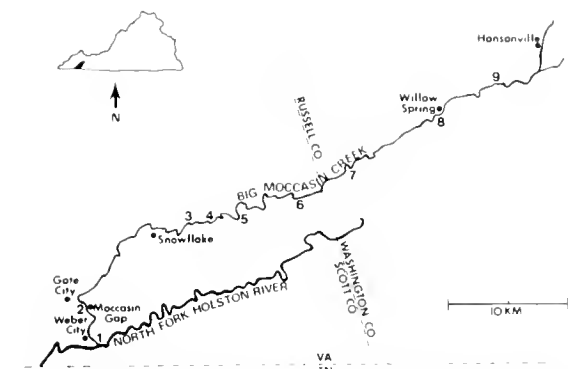


FIG. 1. Stations (1-9) surveyed for mussels in Big Moccasin Creek, Virginia.

14°C; pH, 8.2; dissolved oxygen, 9 mg/l; conductivity, 250  $\mu$ mhos; and hardness, 175 mg/l.

### Methods

Seven sites on Big Moccasin Creek were surveyed by at least three biologists with waterscopes during low water flows in 1979 and 1980. Two of these sites were at locations surveyed earlier in this century by Ortmann (1918). Live specimens or recently dead (lustered) shells were recorded at each station, which included about 0.4 km of stream bottom. Collections at two additional sites (stations 3 and 7) sampled during summer 1977 (Steve Ahlstedt, TVA, personal communication) are included with our survey results. Reference material is housed at Virginia Polytechnic Institute and State University.

### Collecting Stations

1. Above confluence with the North Fork of the Holston River on state route 614, 2.2 km east of route 23 at Wilhelm (river kilometer 0.0; lat. 36°36'32"N long. 82°32'40"W; Scott County). Mussels were uncommon.
2. Adjacent to a state picnic area on state route 23, Moccasin Gap (river kilometer 4.0; lat. 36°38'00"N, long. 82°33'10"W; Scott County). No mussels were collected.
3. Adjacent to state route 613 north of Snowflake (river kilometer 28.8; lat. 36°41'17"N, long. 82°27'56"W; Scott County). Mussels were uncommon.
4. McConnell Mill at intersection of state routes 613 and 687 (river kilometer 32.8; lat. 36°41'43"N, long. 82°26'56"W, Scott County). Mussels were uncommon.
5. Bridge on state route 613, 100 m east of state route 891 intersection (river kilometer 45.1; lat. 36°42'30"N, long. 82°23'55"W; Scott County). Mussels were uncommon.

6. Dean's Farm on state route 613, 1.9 km west of Russell-Scott county line (river kilometer 52.6; lat. 36°43'00"N, long. 82°21'15"W; Scott County). Mussels were abundant.
7. Adjacent to state route 613 just south of Collinwood (river kilometer 58.4; lat. 36°44'00"N, long. 82°19'15"W; Russell County). Mussels were uncommon.
8. Fugate's Farm on state route 613, 0.4 km south of Willow Spring (river kilometer 75.6; lat. 36°46'30"N, long. 82°14'18"W; Russell County). Mussels were common.
9. Owen's Farm at the intersection of state routes 676 and 677 (river kilometer 82.6; lat. 36°47'30"N, long. 82°11'50"W; Russell County). Mussels were abundant at this site, having an average density of 18.7 mussels/m<sup>2</sup> (Zale and Neves 1982).

### Results and Discussion

A total of eight species of freshwater mussels were collected in Big Moccasin Creek (Table 1). Ortmann (1918) reported 14 mussel species at Moccasin Gap (our station 2) and two species at Willow spring (our station 8). We collected two species from Moccasin Gap and six species near Willow Spring. Based on the earlier and current collection records, the following species have apparently been extirpated from the creek: *Ptychobranchus subtentum*, *Lampsilis ovata*, *Dynomia capsaeformis*, *Quadrula cylindrica*, *Pegias fabula*, *Alasmidonta marginata*, and *Fusconia cuneolus*. *Leringtonia dolabelloides* was not reported by Ortmann (1918), but we collected this species at three stations. No recent or relic shells of the endangered *F. cuneolus* were found.

Results of this survey and water quality data from the U.S. Geological Survey and the Virginia State Water Control Board (1976) indicate that the lower 10 km of Big Moccasin Creek has been subjected to water quality degradation from urban development. At Moccasin Gap, stream alterations resulting from road construction, housing development, and channelization were readily apparent. The State Water Control Board (1976) reported that treated sewage discharge at Gate City and raw sewage discharge from Weber City created severe pollution with fecal coliform bacteria and high biological oxygen demand in BMC, particularly during summer. This degradation in water quality surely has adversely affected all downstream biota.

The diverse mussel fauna that once occurred

Table 1. Checklist of mussel species collected (X) from Big Moccasin Creek, 1977-1980.

Mussel Species	Station No.								
	1	2	3	4	5	6	7	8	9
<b>Anodontinae</b>									
<u>Alasmodonta minor</u> (Lea, 1845)							X		X
<b>Lampsilinae</b>									
<u>Lampsilis fasciola</u> (Rafinesque, 1820)			X	X	X	X	X	X	X
<u>Medionidus conradicus</u> (Lea, 1834)		X	X	X	X	X	X	X	X
<u>Villosa nebulosa</u> (Conrad, 1834)	X		X	X	X	X	X	X	X
<u>Villosa vanuxemi</u> (Lea, 1838)	X	X	X	X	X		X	X	X
<b>Unioninae</b>									
<u>Fusconaia barnesiana</u> (Lea, 1838)	X		X	X	X	X	X	X	X
<u>Lexingtonia dolabelloides</u> (Lea, 1840)			X			X	X		
<u>Pleurobema oviforme</u> (Conrad, 1834)	X		X	X	X	X	X	X	X

in lower Big Moccasin Creek has been eliminated. In contrast the upper watershed has remained rural, and the water quality and biota have apparently remained essentially unchanged over the past 70 years. Recent improvements in water quality below Moccasin Gap may allow the gradual recolonization by mussels either from upstream areas or from the North Fork of the Holston River.

#### ACKNOWLEDGMENTS

We thank Lynn Russell Weaver and Jane Bain for assisting with the mussel survey, Steve Ahlstedt for providing the two complementary collections, and David H. Stansbery of the Ohio State University for confirming several identifications. Funding for this work was provided by the Virginia Commission of Game and Inland Fisheries.

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## MOLLUSCA OF THE ROCKY SHORES OF EAST CENTRAL VERACRUZ STATE, MEXICO

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### ABSTRACT

*The molluscan fauna of the Punta del Morro-Punta Delgada region, of east central Mexico located approximately 75 km north of Veracruz, was studied during June, 1973, August, 1976, and March and October, 1977. One hundred twenty-one species (55 alive) consisting of 80 Gastropoda, 36 Pelecypoda, 3 Polyplacophora, and 2 Cephalopoda were collected or observed from the volcanic rocky shores of this region.*

The lack of natural rocky shores in the north and northwestern Gulf of Mexico excludes extensive hard-bottom shore communities. Limited fauna and flora, however, have become established on the various man-made jetties along the Gulf coast (Whitten, et al., 1950). The most northern natural rocky shore areas in the southwestern Gulf are located on the eastern coast of Mexico. The first is a minor limestone protuberance at Punta Jerez, Tamaulipas, and the second is an intrusive Cenozoic volcanic outcropping in the Punta del Morro-Punta Delgada, Veracruz, region (Galtsoff, 1954).

This paper is based upon the mollusks collected from the Punta del Morro-Punta Delgada region, Veracruz, Mexico (Atlantic). The purpose of this investigation is to describe the rocky shore molluscan populations of this unique Gulf of Mexico shore community, especially noting habitat distribution and ecological zonation.

The molluscan fauna of the southwestern Gulf of Mexico was first reported by F. C. Baker (1891). This expedition, under the direction of Professor Angelo Heilprin, collected mollusks from the beaches, islands, and shallow reefs around Veracruz. Sixty-seven years later, Moore (1958) collected 24 species of mollusks by wading and snorkeling on Blanquilla Reef, located approximately 90 km south-southeast of Tampico. Chavez, et. al. (1970) listed 126 species from the lagoon of Lobos Reef, about 10 km south of Blanquilla Reef. A few species of mol-

lusks common to or characteristic of different ecological zones at La Blanquilla Reef, located off Veracruz, were reported by Villalobos (1971). Tunnell (1974) conducted a comprehensive study of the mollusks of Lobos Reef and Enmedio Reef, 15 km southeast of Veracruz, during May and June, 1973. He reported 220 species from Lobos and 219 from Enmedio (290 together). Included in his study were discussions concerning the zoogeographical distribution and ecological distribution of species within the different reef biotic zones.

Rice and Kornicker (1962 and 1965, addendum) provided environmental and distributional data for 149 species from Alacran Reef along the outer edge of the Campeche Bank. Ekdale (1974), who sampled the benthic invertebrate fauna on the western side of the Yucatan Strait, collected 316 species of mollusks. He grouped the mollusks into five major habitat assemblages, each with a set of characteristic species.

Molluscan investigations in the Caribbean have been published from Puerto Rico and the Virgin Islands by McLean (1951); Coomans (1958); Usticke (1959); Warmke and Abbott (1961); and Weber (1961). Rehder (1962) and Work (1969) reported on Los Roques, Venezuela, and Abbott (1958) on Grand Cayman.

Mollusks from the Yucatan Peninsula have been listed by Weisbord (1926) and Jaume (1946). Olsson and McGinty (1958) and Radwin (1969) compiled a list of mollusks from the Carib-

bean coast of Panama, and Houbrick (1968) did the same for Costa Rica.

### Study Area

The Punta del Morro-Punta Delgada region lies approximately 75 km north of Veracruz (Fig. 1). These volcanic outcroppings are the eastern most extension of the Volcanic Cordillera which extends across Mexico from the west coast to the east coast.

Seven prominent volcanic rocky points are found in the Punta del Morro-Punta Delgada region (Fig. 2). Much confusion exists concerning the names of the various points. Ernesto Chavez of the Escuela Nacional de Ciencias Biologicas, Mexico, D.F. (*pers. comm.*) has provided a list of the more commonly used names of these points. Names which are occasionally used

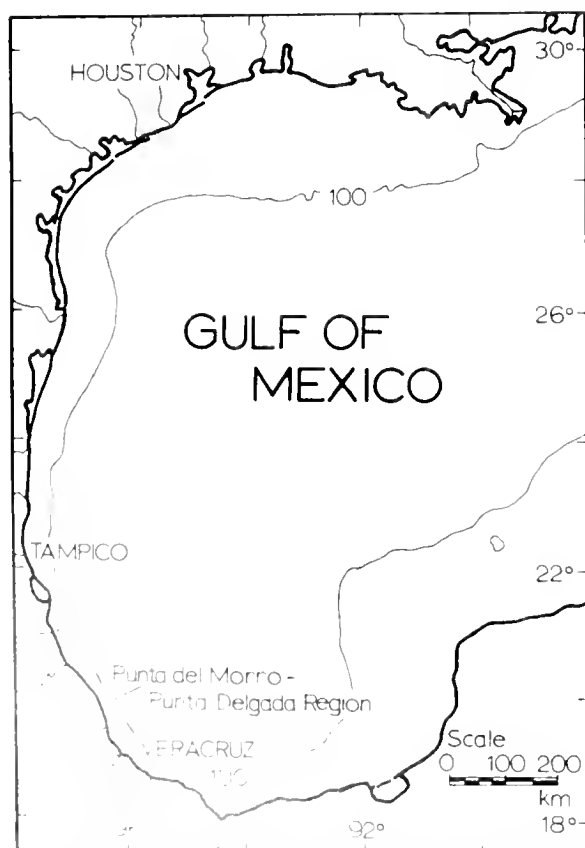


FIG. 1. Map of the Gulf of Mexico showing the Punta del Morro-Punta Delgada region. Bathymetry contoured in fathoms.

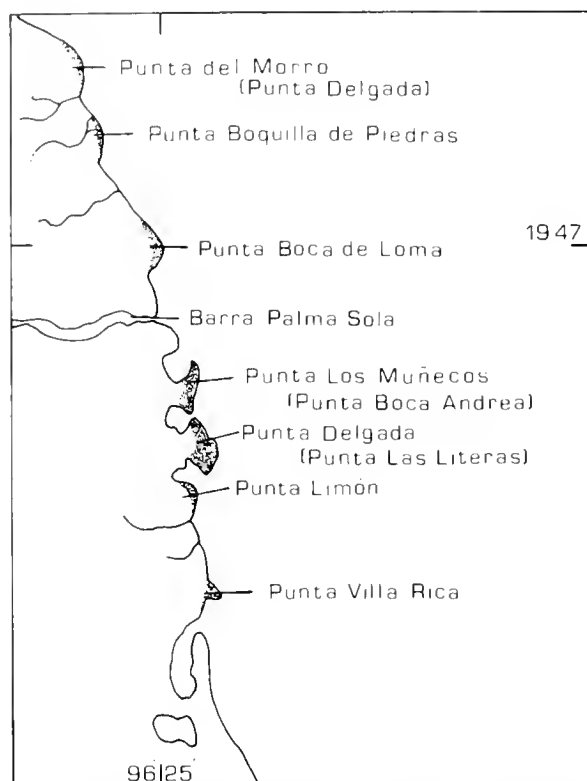


FIG. 2. Map of the Punta del Morro-Punta Delgada region showing the seven prominent rocky points. (Adapted from: Comisión Intersecretarial Coordinadora Del Levantamiento De La Carta Geográfica De La República Mexicana Veracruz 14Q-VI)

by either local residents or listed on other maps are in parentheses following the names provided by Chavez.

Extensive collecting was done exclusively at two points: Punta del Morro ( $19^{\circ}52'15''\text{N}$ ,  $96^{\circ}27'30''\text{W}$ ); and Punta Boquilla de Piedras ( $19^{\circ}51'15''\text{N}$ ,  $96^{\circ}26'45''\text{W}$ ). These points were chosen for their accessibility and differing physiological features.

There is a large variation in available types of habitats on these rocky shores, ranging from steep, rough jagged boulders, which receive full energy of the waves breaking on them (Figure 3) to high and low tide pools (Figure 4) to shallow calm-water areas which are commonly lined with small, smooth rocks and pebbles located on sandy beaches and behind larger boulders (Figure 4 and 5). The large grapsid crab *Grapsus*



FIG. 3. Steep rocky cliffs, approximately 60 m high, at Punta Los Muñecos (Punta Boca Andrea).



FIG. 4. Large, steep jagged boulders and high to low tide pools at Punta del Morro (Punta Delgada).

*grapus* (Linnaeus) is commonly observed scurrying over the outer rocks in the supratidal zone and the small acorn barnacle *Chthamalus fragilis* Darwin dominates the upper intertidal to lower supratidal zones. The mid to lower intertidal areas are dominated by sabellariid polychaetes and luxuriant algal growths, primarily browns with some reds and greens. Subtidally the rocks are covered to a great extent by the zooanthid anemone *Palythoa mamilliosa* (Ellis and Solander), and the sea urchin *Echinometra lucunter* (Linnaeus) is also very abundant.

The Punta del Morro-Punta Delgada region has an annual temperature range of 22-26°C



FIG. 5. Large, steep jagged boulders, protected rocky tide pool, and sandy beach at Punta del Morro in the foreground. Low profile headland, similar to Punta Boquilla de Piedras, in the background.

with an annual rainfall of 1200-1500 mm (Garcia, 1970).

### Methods

Specimens were collected and observed during four trips to the area: June, 1973; August, 1976; and March and October, 1977.

Techniques utilized in the collection of mollusks included: collection and examination of sediment samples from tidepools, beaches, and subtidal substrates for micromollusks; collecting intertidal algae samples for associated mollusks; gathering rock samples for boring and attached species; snorkeling, when weather permitted, for subtidal species; and general collecting involving walking and wading, examining cracks, crevices, tidepools, and overturned rocks.

All samples were put in Whirlpak plastic bags and placed in buckets containing 10% formalin for fixation. Specimens were returned to the lab, washed with freshwater and placed in a 45% solution of isopropanol for preservation. Sediment samples were rinsed with freshwater and placed in an oven for 24 hours at 100°C. After drying, micromollusks were picked from each sample. Algae samples were rinsed over a U.S. Standard Sieve #35 (500u), and any mollusks retained were kept for identification. Algae





TABLE 1 (continued)

Species	Ecological Notation *
Mytilidae	
* <i>Lithophaga aristata</i> (Dillwyn, 1817)	sab
* <i>Brachidontes exustus</i> Linnaeus, 1758	int, sab
Order Pterioidea	
Pteridae	
* <i>Pinctada imbricata</i> Röding, 1798	sbt
Isognomonidae	
* <i>Isognomon alatus</i> (Gmelin, 1791)	sbt
* <i>I. bicolor</i> (C.B. Adams, 1845)	sbt
* <i>I. radiatus</i> (Anton, 1839)	sbt
Ostreidae	
* <i>Crassostrea virginica</i> (Gmelin, 1791)	sht, tp
Pectinidae	
* <i>Argopecten</i> sp.	bd
* <i>Chlamys ornata</i> (Lamarck, 1819)	bd
Spondyliidae	
* <i>Spondylus</i> cf. <i>ictericus</i> Reeve, 1856	hd
Subclass Heterodonta	
Order Veneroidea	
Corbiculidae	
* <i>Polymesoda caroliniana</i> (Conrad, 1839)	bd
Lucinidae	
* <i>Lucina pectinata</i> (Gmelin, 1791)	bd
Chamidae	
* <i>Arctcinella cornuta</i> Conrad, 1866	bd
* <i>Chama macrophylla</i> (Gmelin, 1791)	bd
* <i>Pseudochama radians</i> (Lamarck, 1819)	sbt
Cardiidae	
* <i>Dinocardium robustum</i> (Lightfoot, 1786)	bd
* <i>Trachycardium isocardia</i> (Linnaeus, 1758)	bd
Veneridae	
* <i>Chione cancellata</i> (Linnaeus, 1767)	bd
* <i>C. clenchii</i> Pulley, 1952	bd
* <i>Macrocallista maculata</i> (Linnaeus, 1758)	bd
* <i>Dosinia</i> cf. <i>elegans</i> Conrad, 1846	sed
Macluridae	
* <i>Rangia flexuosa</i> (Conrad, 1839)	bd
Tellinidae	
* <i>Macoma</i> sp.	bd
* <i>Strigilla mirabilis</i> (Philippi, 1841)	sed
Donacidae	
* <i>Donax</i> sp.	bd
Semelidae	
* <i>Semele proficua</i> (Pultenev, 1799)	bd
Order Myoidea	
Myidae	
* <i>Sphenia antillensis</i> Dall and Simpson, 1901	sab
Class Polyplacophora	
Order Chitonida	
Chitonidae	
* <i>Tonicia schrammi</i> (Shuttleworth, 1856)	int
Order Unknown	
Chiton sp. A	int
Chiton sp. B	int
Class Cephalopoda	
Subclass Coleoidea	
Order Sepioidea	
Spirulidae	
* <i>Spirula spirula</i> (Linnaeus, 1758)	bd
Order Octopoda	
Octopodidae	
* <i>Octopus</i> sp.	ob

\*Collected Alive

\*Ecological notation: spt-supratidal zone, int-intertidal zone, sbt-subtidal zone, al-algae associated, sab-sabellarid colony, sed-sediment samples, tp-tidepool, ob-observed, bd-beach drift (shell only)

designating whether the mollusk was collected alive or dead, the specific collecting site or zone, and, in some cases, a notation relating to some ecological aspect which deserves mention. The systematic list follows Keen (1971) except for genera or families which are absent from her coverage of tropical West America, in which case Abbott (1974) was employed. The species are arranged alphabetically within each genus.

### Supratidal zone

*Littorina-Nerita* zonation, common in many

rocky shore areas throughout the Caribbean, characterized the supratidal zone. *Littorina zizac* and *L. lineolata* were commonly found on supratidal rocks and boulders in the upper portion of the supratidal zone. *Littorina zizac* was usually found above *L. lineolata* whenever they occupied the same substrate. Two individuals of *L. nebulosa* were collected from Punta Boquilla de Piedras but are considered uncommon. Located between the *Littorina* zone and the water's edge, *Nerita fulgurans* was observed in large numbers. *Nerita tessellata* and *N. versicolor* were also considered uncommon as only two individuals of each species were collected both from Punta Boquilla de Piedras in March, 1977. *Planaxis nucleus* was observed in close proximity to *N. fulgurans* in the lower portion of the supratidal zone and upper portion of the intertidal zone but was less abundant.

### Intertidal zone

Fifteen species of mollusks (11 Gastropoda, 1 Pelecypoda, and 3 Polyplacophora), were collected from the intertidal zone; only the subtidal zone yielded more species (18). The intertidal zone of the Punta del Morro-Punta Delgada region can be divided into 3 sub-zones: upper, middle and lower intertidal. Each zone can be characterized by certain mollusks.

The upper intertidal zone is characterized by *Siphonaria pectinata*, *Nerita fulgurans*, and *Thais haemastoma*. These species were also found in the supratidal zone but were more abundant in the upper intertidal zone.

Two keyhole limpets, *Diodora cayenensis*, and *Fissurella barbadensis*, and the muricid *Purpura patula* were the characteristic species of the middle intertidal zone. *Fissurella* was the most abundant limpet. One specimen of *Acmaea leucopleura* was collected but considered uncommon. In calm-water tide pools under rocks right at the water line *Planaxis lineatus* appeared gregarious often in clusters of 15-20 individuals, but sometimes as many as 80-100.

The lower intertidal zone was more of an interface with the subtidal zone. *Petalocochus varians* formed extensive mats in this area. *Brachidontes exustus* and *Isognomon bicolor*

were commonly found attached to *Petal-conchus*. The polyplacophorans collected were found in this zone, but only one specimen of each was collected and were considered uncommon.

Of two muricids mentioned above, *Purpura patula* was common on rough water, outer rocks and *Thais haemastoma* was more common on rocks found in moderate to slight wave energy areas.

### Subtidal zone

*Barbatia domingensis*, found to be most abundant in turbulent environments on the Bermuda platform by Bretsky (1967), was the most abundant ark collected from the subtidal zone. *Arca imbricata*, *Arcopsis adamsi*, and *Barbatia candida*, which are perhaps the most conspicuous arks in the shallow waters of Lobos Reef (Tunnell, 1974), were only occasionally collected or observed in the subtidal zone. Locally abundant in the upper portion of this zone were clusters of *Brachidontes exustus* and *Isognomon bicolor*. *Aplysia* cf. *brasiliensis*, *A. dactylomelo* and two unidentified nudibranchs were collected in 1976 while snorkeling.

### Algae

Numerous species of mollusks are found associated with marine algae. Warmke and Almodovar (1963) presented data on mollusk-algae associations of Puerto Rico. They collected 90 species of mollusks from 25 species of algae.

Four species of algae, *Sargassum* cf. *filipendula* C. Agardh, *Padina vickersiae* Hoyt, *Caulerpa racemosa* (Forsk.) J. Agardh, and *Ulva lactuca* Linnaeus were collected at Punta Boquilla de Piedras and examined for mollusks. These four species appeared to be the dominant algae.

Nine species of gastropods were found associated with the four algal species collected. Only two species, *Tricola affinis* and *Caecum pulchellum*, were found exclusively on the algae. *Littorina moleagris* was also found intertidally on the rock. *Caecum vestitum* and *Fossarus orbigny* were found in the sabellariid polychaete colonies, as well as on algae. *Planaxis lineatus* was collected from calm-water tidepools

and algae, while *Nitidella laevigata* was found crawling subtidally on the rocks among the algae.

### Sabellariid polychaete colonies

Sabellariid polychaete colonies were commonly observed covering portions of intertidal boulders. These colonies formed a layer approximately 2-10 cm thick and were composed of agglutinated tubes of sand grains. Larger holes and channels probably formed by wave action were inhabited by numerous crustaceans, polychaetes, and mollusks. *Fossarus orbigny*, *Brachidontes exustus*, and the nestling bivalve *Sphenia antillensis* were the most common mollusks collected from the sabellariid colonies.

### Discussion

Although the majority of the molluscan fauna collected from the Punta del Morro-Punta Delgada region is considered to be Caribbean in origin, many of the families and genera were represented by only one or two species. Tunnell (1974) stated that southwestern Gulf reefs appear to have several reduced or lacking tropical elements which are generally common in areas more centrally located within the Caribbean Province. This situation appears to be the case in the Punta del Morro-Punta Delgada region also. Although not universally accepted, the inshore northern boundary of the Caribbean province is located in the vicinity of Cabo Rojo (Briggs, 1974). This places the study area near the periphery of the Caribbean province where physical and ecological conditions are favorable for tropical species, but are far from being optimal. The molluscan fauna of the Punta del Morro-Punta Delgada rocky shores would therefore, most accurately be described as "depauperate Caribbean."

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## SIX NEW SPECIES OF INDO-PACIFIC TEREBRIDAE (GASTROPODA)

Twila Bratcher

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and

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While doing research for a forthcoming book, we have come across a number of undescribed

terebrid species, some in museums, others from private collectors. Some other species were

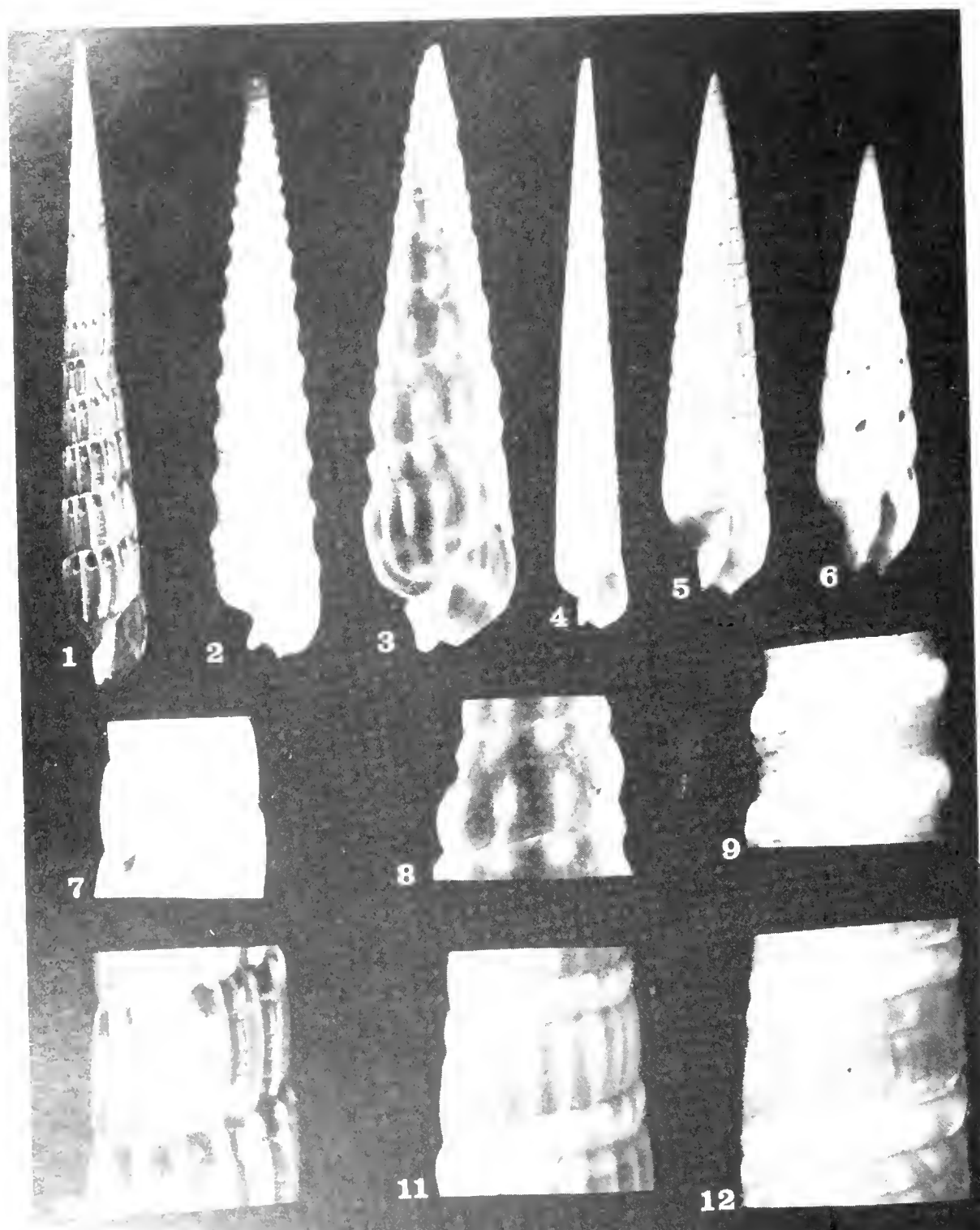


PLATE 1. 1: *Duplicaria bratcheri* Bratcher & Cernohorsky, new species. Holotype, LACM no. 1968, 54.4 mm. 2 & 9: *Duplicaria bratcheri* Bratcher & Cernohorsky, new species. Holotype, LACM no. 1969, 26.1 mm. 3 & 8: *Duplicaria mozambiquensis* Bratcher & Cernohorsky, new species. Holotype NM no. H7843, 22.3 mm. 4 & 12: *Terebra caddeyi* Bratcher & Cernohorsky, new species. Holotype NM no. H7844, 22.3 mm. 5 & 11: *Duplicaria baileyi* Bratcher & Cernohorsky, new species. Holotype NM no. H7845, 22.3 mm. 6 & 10: *Duplicaria baileyi* Bratcher & Cernohorsky, new species. Holotype MNHN, 17.9 mm.

represented only by a single specimen, and we will wait for more material before describing them. Six are being described here.

***Terebra burchi* new species**

(Figs. 6, 7)

**Diagnosis:** A pure-white shell with small brown dots scattered at random just below the suture and with a broadband of yellowish brown on the base of the body whorl.

**Description:** Shell about 18 mm in length, with 12 whorls of teleoconch; color pure-white with small yellowish brown dots scattered at random immediately anterior to the suture and with the same color on the base of the body whorl; outline of whorls convex; protoconch with 1½ whorls remaining (paratype with intact protoconch of 3½ amber conical whorls); sculpture of slightly arcuate axial ribs from suture to suture, 13 on penultimate whorl; ribs well-developed, quite sharp, and narrower than interspaces; interspaces with 5 evenly-spaced grooves, the posterior being deep; interstitial grooves not crossing ribs; no subsutural band; body whorl with ribs fading at periphery; 8 grooves anterior to periphery, 6 posterior; aperture quadrate, with basal plication; columella recurved.

**Dimensions:** Holotype 17.9 × 4.3 mm. Paratypes from 18.8 × 4.3 to 22.4 × 5.4 mm.

**Type locality:** Northern Mozambique Channel (12 45'S; 45 18'E), at 15–20 m, Benthedi Expedition sta. 32.

**Type Material:** Holotype MNHN Paris. Paratypes LACM no. 1971 (1); MNHN (2); Bratcher coll. (2); Cernohorsky coll. (2); Tursch coll. (2).

**Distribution:** From Mozambique and Papua New Guinea; 2 to 20 m. Also Philippines.

**Discussion:** There are several other Indo-Pacific terebrids with dark areas anterior to the periphery of the body whorl and scattered spots below the suture. None of them has a pure-white background. *Terebra amoena* Deshayes, 1859, *T. conspersa* Hinds, 1844, and *T. pertusa* (Born, 1778), all have larger shells with beige to tan backgrounds and have obvious subsutural bands.

This species is named in honor of a late friend and colleague, R. D. Burch.

***Terebra caddeyi* new species**

(Figs. 4, 12)

**Diagnosis:** A long, slender, flat-sided terebrid shell, shiny tan, and with 3 or 4 spiral grooves per whorl.

**Description:** Shell long, slender, with 25 whorls; color shiny tan; outline of whorls straight; protoconch missing; 3 spiral bands, each defined by a spiral groove, occur anterior to suture; posterior band narrow, without nodes; center band of obsolete nodes; anterior band flatter and scarcely noded; no axial sculpture except axial striae; body whorl with deep groove posterior to periphery, followed by 3 weak grooves; aperture small, quadrate; columella curved, with moderately heavy parietal callus; siphonal notch broad.

**Dimensions:** Holotype 52.7 × 6.9 mm. Paratypes from 44.4 × 5.4 to 53.4 × 6.6 mm.

**Type Locality:** Korere Village, Rabaul, Papua, New Guinea, 3 m. in depth, on volcanic sand.

**Type Material:** Holotype LACM no. 1967. Paratypes Bratcher coll. (1); Caddey coll. (2).

**Distribution:** Known only from type locality.

**Discussion:** *Terebra lima* Deshayes, 1857, also has a flat-sided shell, but it lacks the sheen of this species and has almost cancellate sculpture with spiral cords and axial sculpture forming small nodes at intersections. *T. jenningsi* Burch, 1965, has a concave outline, a cord at the periphery of the body whorl, and more spiral grooves. It also lacks sheen. This species is named for P. T. Caddey, who collected the type lot.

***Terebra mactanensis* new species**

(Figs. 1, 10)

**Diagnosis:** A long, extremely slender terebrid shell with dark spots between axial ribs anterior to the suture.

**Description:** Shell extremely slender, long; color, shiny brown with black spots between axial ribs anterior to suture and a row of small white dots at periphery of body whorl; outline of whorls convex; protoconch of 3 white, conical whorls; sculpture of axial ribs from suture to suture, narrower than interspaces; ribs on body whorl terminating at periphery in a white spot; aperture elongate; columella recurved, white; siphonal fasciole extremely heavy, long.

*Dimensions:* Holotype  $54.4 \times 7.2$  mm. Paratypes from  $47.8 \times 6.1$  to  $62.1 \times 8.1$  mm.

*Type Locality:* Punta Egano, Mactan Island, Cebu, Philippine Islands at 200 m.

*Type Material:* Holotype LACM no. 1968. Paratypes Bratcher collection. (1); Marrow collection. (1).

*Distribution:* This species is known only from the type locality.

*Discussion:* One of the paratypes is light orange-brown with dark brown spots between the ribs anterior to the suture. The other is white with a few brown areas anterior to the suture and with extremely faint brown spots at the periphery of the body whorl. All have similar sculpture. There is no Indo-Pacific terebrid species with which *T. mactanensis* could be confused. The white paratype might be compared with *T. fortuneae* Deshayes, 1857, which has an inflated shell with longer whorls, has more spiral sculpture; and has no brown ornamentation. The type lot was collected by Max Marrow.

#### ***Terebra marrowae* new species** (Figs. 2, 9)

*Diagnosis:* A cream-colored terebrid shell with a few small orange-brown dots and with an exceptionally large, blackish mamillate protoconch.

*Description:* Shell medium-sized for the genus; color, cream with a few small scattered orange brown dots, protoconch and first whorls of teleoconch brown; outline of whorls concave in early whorls, flat in later ones, with convex subsutural band; protoconch of  $1\frac{1}{2}$  broad, mamillate blackish brown whorls; subsutural band of large pearl-like nodes, occasionally spotted between by orange-brown; suture shallow; subsutural groove deep, narrow; subsutural band followed by a narrow, almost smooth, inconspicuous band, becoming slightly nodulous on last 2 whorls; remainder of whorl finely cancellate with 2 spiral cords per whorl, forming shallow pits between intersections; body whorl with finely cancellate sculpture ending posterior to suture; spiral cords only continuing to aperture; aperture short, quadrate; columella short.

*Dimensions:* Holotype  $26.1 \times 5$  mm. Paratypes from  $21.4 \times 4.8$  to  $32.1$  (Apex missing) to 6.4 mm.

*Type Locality:* Cleaverville, N.W. Australia; intertidal.

*Type Material:* Holotype LACM no. 1969. Paratypes Bratcher coll. (1); Caddey coll. (2); Cernohorsky coll. (1); Cooper coll. (2).

*Distribution:* Northwest Australia, intertidal.

*Discussion:* The most outstanding feature of this species is the extremely large blackish brown or purplish brown mamillate protoconch, with a lighter brown or purplish area extending through two to four whorls of the teleoconch, becoming progressively lighter. The sculpture of some of the paratypes is finer than that of the holotype, with smaller nodes on the subsutural band. The color varies from white to yellowish white with a white subsutural band. All specimens except one have a few tiny scattered brown dots, and that one was collected dead. Two of the paratypes have brownish pin-point dots at the periphery of the body whorl.

There are several other Indo-Pacific terebrid species with cancellate sculpture, all of which are easily separable from *Terebra marrowae*. *T. swobodai* Bratcher, 1981, is more slender, has convex whorls and very heavy, rough sculpture with small nodes forming where axial and spiral cords cross. *T. elliscrossi* Bratcher, 1979, and *T. amanda* Hinds, 1844, both have slender, non-mamillate protoconchs of more than  $1\frac{1}{2}$  whorls. Although *T. fenestrata* Hinds, 1844, has a mamillate protoconch, it is about  $\frac{1}{3}$  as large as that of *T. marrowae*, and the sculpture of the teleoconch is extremely coarse and heavy. This species is named in honor of Lorna Marrow, who collected the holotype.

#### ***Duplicaria baileyi* new species** (Pl. 5, 11)

- 1965 *Duplicaria australis* (E. A. Smith), J. Cate & R. D. Burch, *Veliger* 6(3):145; 1967 Cernohorsky, *Mar. Shells Pacific* 1:208, pl. 52, fig. 392. [non *Terebra australis* E. A. Smith, 1873].  
1966 *Duplicaria* (*Duplicaria*) sp. Cernohorsky & Jennings, *Veliger* 9(1):58, pl. 6, fig. 44.  
1978 *Terebra australis* (E. A. Smith), Hinton, *Guide Australian Shells*, pl. 59, fig. 6. [non *Terebra australis* E. A. Smith, 1873].

**Diagnosis:** A beige *Duplicaria* shell with a few yellowish brown splotches scattered irregularly and with brown anterior to the periphery of the body whorl.

**Description:** Shell medium sized, with 13 whorls of teleoconch; color, beige with a few reddish brown splotches and dots scattered at random, and with the same color anterior to the periphery of the body whorl; outline of whorls slightly convex; protoconch of  $4\frac{1}{2}$  pink, translucent, conical whorls; axially ribbed subsutural band defined by shallow groove, with deeper punctations between ribs; remainder of whorl with straight axial ribs contiguous with ribs on band; interspaces about equal to ribs, smooth; body whorl with ribs ending at periphery; periphery marked with light band between rib endings and light-brown area; aperture elongate; columella recurved; siphonal fasciole striate, with moderate keel.

**Dimensions:** Holotype  $24.9 \times 5.3$  mm. Paratypes  $21.5 \times 4.5$  to  $40.0 \times 7.9$  mm.

**Type Locality:** Guadalcanal, Solomon Islands  $9^{\circ} 25'S$ ;  $159^{\circ} 56'E$ ; in sand at 20 m.

**Type Material:** Holotype LACM no. 1970. Paratypes ANSP no. 352482 (1); AM no. 132464 (1); CAS no. 60674 (1); MCZ no. 290426 (1); MORG no. 21.275; NM no. H-766 (1); USNM no. 782262 (1); Bratcher coll. (2); Cernohorsky coll. (2); Morrow coll. (2).

**Distribution:** Mozambique to the Philippines and the Solomon Islands; from intertidal to 100 m.

**Discussion:** The number of axial ribs varies from 20 to 29 on the penultimate whorl, and the basic color varies slightly from cream to beige. The brown splotches may vary in number and size, but they are always inconspicuous. *Duplicaria teramachii* Burch, 1965, is somewhat similar in color pattern although it has a broad band of reddish brown instead of the occasional interrupted blotches. It also has a narrower apical angle, flatter subsutural band, and shorter whorls. This species is named in honor of Brian Bailey who collected the holotype.

***Duplicaria mozambiquensis* new species**

(Figs. 3, 8)

360 *Terebra gracilis* Reeve, *Conch. Icon.* 12, pl. 24, fig. 131

[non Lea 1833; non Gray, 1834] Hab.: Africa; holotype BM(NH). 1874.10.29.2; 22.0 mm.

**Diagnosis:** A *Duplicaria* with extremely inflated early whorls, a punctate subsutural groove, and a narrow, noded subsutural band.

**Description:** Shell color light-brown with ivory ribs, nodes, and narrow peripheral stripe on body whorl; outline of whorls convex; protoconch mamillate with  $1\frac{1}{2}$  brown, moderately inflated embryonic whorls; sculpture of early whorls of teleoconch consisting of a narrow subsutural band with wide-spaced round nodes (8 or 9), and below each node an arcuate rib almost noded in center, giving an angulate outline to the early whorls; a punctate subsutural groove developing after the 3rd whorl of teleoconch; ribs on remainder of whorl remaining wide-spaced, sharp, and arcuate, but losing the angulate form on later whorls (12 on penultimate whorl); nodes on subsutural band angulate on later whorls; body whorl with sharp ribs continuing below periphery to keel of siphonal fasciole; aperture elongate; columella almost straight.

**Dimensions:** Holotype  $22.3 \times 5.6$  mm. Paratypes from  $17.0 \times 4.4$  to  $33.0 \times 6.8$  mm.

**Type Locality:** Mozambique, trawled off Chinde Island.

**Type Material:** Holotype Natal Museum no. H7843/T2541. Paratypes in BM(NH) 198021; Natal Museum nos. J2973/T2542 (1), 566/T2543 (1), B2137/T2544 (1), H765/T2545 (2); Bratcher coll. (1).

**Distribution:** From Durban, South Africa, to Mozambique.

**Discussion:** Four of the paratypes are the same color as the holotype; one is peach color; and two are ivory. Some individuals have small, inconspicuous nodes at the posterior end of the axial ribs. Some have more numerous, less widely spaced ribs.

*Duplicaria spectabilis* (Hinds, 1844) has similar sculpture, but it has a distinctive color pattern of rich brown and cream stripes, and a protoconch of  $2\frac{1}{2}$  whorls. *Duplicaria evoluta* Deshayes 1859, has a broad subsutural space but no groove. It has axial ribs on the subsutural band instead of round nodes, and the early

whorls are quite flat in outline. This is the same species as *Terebra gracilis* Reeve, 1844, a name which was preoccupied.

*Abbreviations* have been used for a number of institutional collections cited in this paper. They are:

AM—Australian Museum

ANSP—Academy of Natural Science of Philadelphia.

CAS—California Academy of Sciences.

LACM—Los Angeles County Museum of Natural History.

MCZ—Museum of Comparative Zoology, Harvard University.

MNHN—Muséum National d'Histoire Naturelle, Paris.

MORG—Museu Oceanográfico de Rio Grande, Brazil.

NM—Natal Museum, South Africa.

#### ACKNOWLEDGMENTS

We wish to thank the following for the loan of

type material for this study: Brian Bailey of Honiara, Solomon Islands; Dr. Philippe Bouchet of MNHN Paris; P. T. Caddey of N.S.W., Australia; Dr. George Davis of ANSP; Dr. R. Kilburn of NM; Max Marrow of Victoria, Australia; Dr. Ben Tursch of Brussels, Belgium; Dr. Joseph Rosewater of USNM.

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## THE FRESHWATER MUSSELS (NAIADS) OF BIG INDIAN CREEK, A SMALL SOUTHERN INDIANA TRIBUTARY OF THE OHIO RIVER (BIVALVIA: UNIONIDAE)

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#### ABSTRACT

*A 1979-81 survey of Big Indian Creek in southern Indiana produced a total of 16 species of freshwater mussels (Naiads). In addition to these unionid species, the exotic clam Corbicula fluminea was also found to be present throughout the stream. The faunal make-up proved to be typically Ohioan in nature. The most common species were Lampsilis r. luteola, Lampsilis ventricosa and Amblema p. parva. Lampsilis fasciola, Leptodea fragilis and Toxolasma parvus were each represented by a single specimen.*

In their recent book, *The Mollusca of Indiana*, Goodrich and Girty (1944) brought

together, in a condensed form, all the early work done on the freshwater mussels in Indiana



streams. A more recent work by Krumholz *et al* (1970) provided valuable information on the White and Wabash Rivers. Most of the published information available on the mussels of Indiana is in fact concerned with the naiad faunas of the larger rivers. There appears to be a dearth of information available on the mussels of small streams, and in particular those streams of southeastern Indiana. It is the purpose of this paper to report work on such a stream, Big Indian Creek, a tributary of the Ohio River located in southern Indiana.

Big Indian Creek originates in the low-rolling hill section of southeastern Indiana, locally known as Floyd Knobs, and flows in a generally southwesterly direction to its confluence with the Ohio River at the village of New Amsterdam some fifty river miles downstream of Louisville, Kentucky. The stream presently exists in a fairly undisturbed condition. Big Indian Creek flows through land that has for over a hundred years been dedicated to agricultural use. A good percentage of the lower portion of the creek flows through Harrison/Crawford State Forest. The only towns of any size in this drainage are the villages of Crandall and Corydon, with a combined total population of less than one thousand inhabitants. Water quality is apparently good, and the only possible source of pollution would be that which results from limited agricultural activities within the floodplain. The substrate is primarily limestone bedrock with an occasional sand and gravel bar. There is very little evidence of excessive silt deposition anywhere along the stream's course.

### Methods

During the summers of 1979 and 1981, Big Indian Creek was surveyed for freshwater mussels at irregular time intervals. Seven collecting stations were established. Fresh dead shells were handpicked from the water and shore line. Very old, severely weathered specimens were discarded and only specimens of those species considered to be part of the present naiad fauna are included in this report. Specimens were cleaned and cataloged in the Marshall University Malacological Collections. Voucher specimens have

been placed in the Ohio State University Museum of Zoology. Scientific names are those used by Stansbery (1980).

### Collecting Stations

1. Under bridge on Indiana St. Rt. 335, .4 mi S of St. Rt. 64, 1 mi N of village of Crandall; Harrison County, Indiana.
2. Take St. Rt. 335 SW of Crandall to Bethlehem Cemetery Rd., .5 mi N on Cemetery Rd. to Indian Creek; Harrison County, Indiana.
3. Take St. Rt. 135 S of village of New Salisbury to unnamed, unimproved dirt road, .4 mi S of Southern Railway tracks, .7 mi E on dirt road to bridge; Harrison County, Indiana.
4. Take St. Rt. 135, 3.7 mi S of New Salisbury to Conrad Cemetery Rd., .3 mi E to Creek; Harrison County, Indiana.
5. Take St. Rt. 135 2.5 mi SW of Corydon to Heidelberg Church Rd., then Mathis Rd. 1 mi to Creek; Harrison County, Indiana.
6. Take St. Rt. 135 to Heidelberg Church Rd., then to Valley View Rd. 1 mi to creek, Ca 3.5 mi SW of Corydon; Harrison County, Indiana.
7. Indiana St. Rt. 335, .1 mi E of Indiana St. Rt. 135, Ca 2 mi S of New Salisbury; Harrison County, Indiana.

Table 1. Freshwater Naiads collected 1979-81 from Big Indian Creek. Species listed by site.

Species	Station						
	1	2	3	4	5	6	7
<i>Anodonta p. grandis</i> Say, 1829							X
<i>Strophitus u. undulatus</i> (Say, 1817)	X	X					X
<i>Alasmidonta viridis</i> (Raf., 1820)	X	X	X	X	X		X
<i>Lasmigona complanata</i> (Barnes, 1823)						X	X
<i>Lasmigona costata</i> (Raf., 1820)	X	X	X				X
<i>Anblema p. plicata</i> (Say, 1817)		X	X	X	X	X	X
<i>Fusconaia flava</i> (Raf., 1820)	X	X	X	X	X	X	X
<i>Elliptio dilatata</i> (Raf., 1820)							X
<i>Leptodea fragilis</i> (Raf., 1820)							X
<i>Putamius alatus</i> (Say, 1817)						X	
<i>Troxolasma parvus</i> (Barnes, 1823)				X			
<i>Villosa l. iris</i> (Rea, 1828)				X	X	X	X
<i>Villosa lanosa</i> (Conrad, 1834)			X	X	X	X	X
<i>Lampsilis radiata luteola</i> (Ham., 1819)	X	X	X	X	X	X	X
<i>Lampsilis ventricosa</i> (Barnes, 1823)			X	X	X	X	X
<i>Lampsilis fasciola</i> Raf., 1820						X	
<i>Corbicula fluminea</i>		X	X		X		

### Summary

Survey collecting at seven stations along Big Indian Creek yielded a total of sixteen species of freshwater Naiads plus the exotic Asiatic import *Corbicula fluminea* (Table 1). Most species were present in good numbers at several different localities. Five species (*Anodonta grandis*, *Leptodea fragilis*, *Elliptio dilatata*, *Toxolasma parvus* and *Lampsilis fasciola*) were, however, found at only one locality each.

None of the species found is currently considered to be rare or endangered. The faunal make-up of this small stream is typically Ohioan and is fairly similar to that found in Floyd's Fork and Salt River (Taylor, 1980) which enter the Ohio River from the south in the proximity of

the mouth of Big Indian Creek which enters from the north.

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### MEETINGS

- July 14-17. C.O.A. (Conchologists of America). Sanibel Island, Florida.
- July 19-23. A.M.U. (American Malacological Union). New Orleans, Louisiana.

### SHELL SHOWS

- July 30 - Sept. 1. Jacksonville Shell Show. Jacksonville Beach, Florida.
- June 20-23. 15th annual meeting of the Western Society of Malacologists at the University of Redland, CA.

### RECENT DEATHS

**Wataru W. Sutow, M.D.**, well-known cancer expert, author of medical textbooks, and active member of the Houston (Texas) Shell Club, died Dec. 20, 1981, at the age of 69. He was born Aug. 3, 1912, in Guadalupe, California. See *American Malacologists* (1973), p. 457 and *Texas Conchologist* (1982), vol. 18, no. 2, p. 25.

**Carlos G(uillermo) Aguayo**, leading Cuban malacologist, exiled in Puerto Rico, died Feb. 12, 1982, at the age of 83, in Puerto Rico. He was born in Havana, Cuba on Dec. 19, 1899, and became a professor at the University of Puerto Rico in Mayaguez in 1958. He published over 130 papers on mollusks, especially those of the Caribbean. He was a Guggenheim Foundation Fellow in 1931-33. (see *American Malacologist* 1981, p. 188).

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# MASSIVE DESTRUCTION OF SCLERACTINIAN CORALS BY THE MURICID GASTROPOD, *DRUPELLA*, IN JAPAN AND THE PHILIPPINES<sup>1</sup>

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## ABSTRACT

*Aggregates of the muricid gastropods Drupella fragum, at Miyake-jima, Japan, and Drupella rugosa, at Mactan Island, Cebu, Philippines, were noted to result in widespread destruction of scleractinian corals. Destruction was limited to fast-growing foliate forms such as Montipora, Acropora, Pocillopora, etc., but other genera, e.g. Porites, Goniopora, Favia, Fungia, etc., were avoided. Muricid predation at Mactan appeared to represent a biological control on coral reef structure, "weeding out" fast growing forms and providing space and settlement sites for other coral species, thus increasing diversity over time. At Miyake-jima, in the warm temperate waters of southern Japan, Acropora spp. are dominant. Coral destruction by Drupella fragum has been massive on Acropora reefs at Miyake-jima, amounting to as much as 35% of our study reef (Toga Reef No. 1) in two years. The sudden population explosion of D. fragum in 1976 at one site on the island and in 1980 at another location correlates with massive siltation from heavy bulldozing on the volcanic island, followed by heavy rainfall. A hypothesis to explain this correlation is presented.*

Although many marine animals are known to feed on hermatypic corals (Robertson, 1970; Reese, 1977; Taylor, *et al.*, 1980), only the asteroid *Acanthaster planci* has previously been reported as representing a serious threat to coral reefs (Randall, 1972; Branham, 1973; Endean, 1973; and others). Robertson (1970) reported that certain species of prosobranch gastropods of the muricid genus *Drupella* are known as predators on scleractinians of various genera and that some have been found living in fairly large colonies among the branches of and under stony corals. However, to our knowledge,

population explosions of *Drupella* with widespread coral destruction have yet to be reported.

Since 1976, population explosions of varying sizes involving *Drupella fragum* (Blainville, 1832) have been observed annually at the island of Miyake-jima (34°05'N, 139°30'E), one of the Izu Islands of southern Japan. The combination of heavy predation of *D. fragum* and *Acanthaster planci* (see Moyer, 1978) have destroyed much of the island's coral fauna. Since 1979, a similar phenomenon, but with less destructive results, has been under observation at Mactan Island, Cebu, Philippines (10°18'N, 123°54'E), involving *Drupella rugosa* (Born, 1778) and various species of branching corals. In this

<sup>1</sup>Contribution No. 36, Tatsuo Tanaka Memorial Biological Station.

paper we document the role of *Drupella fragum* and *D. rugosa* in the destruction of corals and identify them as potentially harmful to coral reefs.

### Methods and Materials

Early observations of *Drupella* predation at Miyake-jima were made incidental to behavioral studies on reef fishes from 1976 to 1979. The extent of the damage caused by the gastropods was not realized until 1980. Accurate measurements and observations of *Drupella* destruction were obtained for two months in 1980 and one month in 1981. Data were collected both diurnally and nocturnally using scuba. Specimens were collected as they fed on coral polyps 2 to 4 hours after sunset and as they were concealed under coral branches by day. At Mactan Island, three transects, each measuring 100 m in length, were placed parallel to shore, 4 m apart and at depths ranging from 1–2 m, at two study sites (Tambuli Beach and Malingin Beach) for the purpose of coral community studies. At every .25 m point along these transects, a point sample was made using a small weight (5 mm in diameter). This provided 1200 points of information for each reef site. Data were collected from 1979–1981. The percent of dead and grazed corals was recorded at each site according to specific genera of corals and observations of *Drupella rugosa* swarms were recorded, both diurnally and nocturnally. Specimens were collected as they aggregated under coral branches by day. All specimens from both Japan and the Philippines are deposited in the mollusk collection of the American Museum of Natural History (AMNH). Underwater photographs were taken by Moyer at Miyake-jima and by Ross at Mactan Island.

The four species of neogastropods observed feeding on the corals at Miyake-jima and Mactan are referable to the superfamily Muriceae. Three are species of *Drupella*, a genus assigned to the Thaidinae, a subfamily of the Muricidae (Emerson and Cernoborsky, 1973; Ponder, 1973). The fourth species belongs to the nominate genus *Coralliophila* of the Coralliophilidae, which are anatomically similar to the Muricidae, but lack a radium. The radular denti-

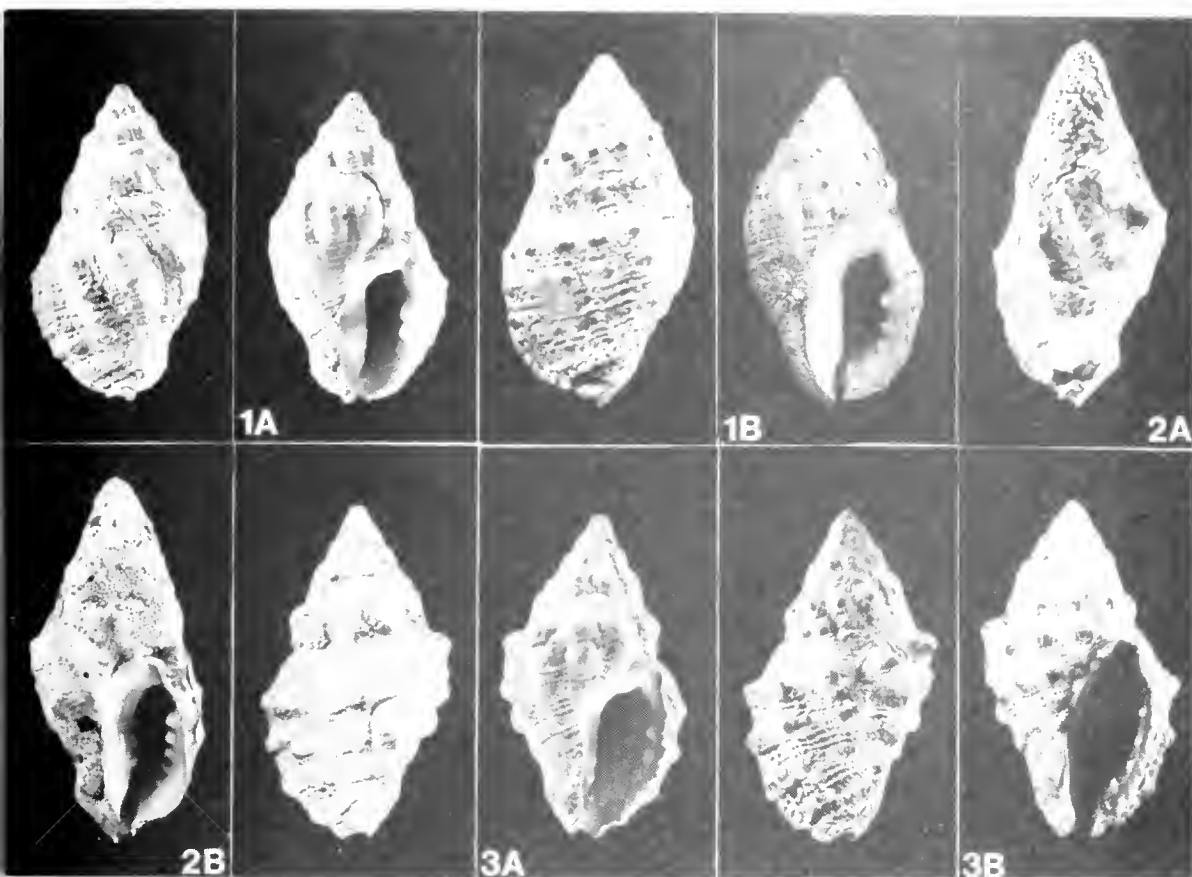
tion of *Drupella* is atypical of the Muricidae, in which three teeth are aligned in each transverse row, with the central tooth commonly armed with three cusps and the triangular lateral teeth distally cuspid. In *Drupella*, the much larger and more slenderly elongated lateral teeth are commonly basally denticulate on the inner margin and distally terminate in a hooked tip (Cernohorsky, 1969, pp. 303–307, figs. 8–11). These radular modifications probably reflect an adaptation to a specialized mode of feeding (Cooke, 1895; Arakawa, 1958; Wu, 1965; Robertson, 1970; and others). The reed-like lateral teeth apparently sweep the polyps of coral onto the basal denticles of the lateral teeth and the cusps of the central teeth where the food particles are abraded (*cf.* Cernohorsky, 1969, p. 304; Fankboner, 1970, p. 15; Taylor, 1976, p. 185).

### Results

#### *Species identification*

*Japan:* The two Miyake-jima forms of *Drupella* clearly represent distinct species. The specimens that were found in massive clusters on coral are identified as *Drupella fragum* (Blainville, 1832). These specimens (Figs. 1A, 1B), which attain a maximum height of 23+ mm, have weakly developed axial ribs (12 per whorl) and an essentially white aperture. The exterior is pale orange-ochre, giving a yellowish-white appearance to the shell. Many specimens have a spirally arranged, brownish maculation between the axial ribs, especially on the body whorl. In some specimens, as many as six faint, orange spots occur on the outer lip and in the interior of the siphonal canal. The identification of these specimens must remain tentative until comparison can be made with the typological specimens of *Purpura fragum* in Blainville's collection, which is deposited in the Muséum National d'Histoire Naturelle, Paris. In the original description, Blainville (1832, p. 203, pl. 9, fig. 4) noted that the yellowish-white shell possessed dark rose nodules and a white aperture. In the present specimens, the nodules in some individuals are dark to pinkish brown.

The second Miyake-jima species, *Drupella elata* (Blainville, 1832, p. 207, pl. 11, fig. 1) [= *D.*



FIGS. 1-3. 1A and 1B, *Drupella fragum* (Blainville), Miyake-jima, Japan; A, all white form, AMNH 203816a; B, maculated form, AMNH 203816b;  $\times 2$ . 2A and 2B, *Drupella elata* (Blainville), Miyake-jima, Japan, AMNH 202766;  $\times 2$ . 3A and 3B, *Drupella rugosa* (Blainville), Mactan Island, Philippines; A, all white form, AMNH 202664a; B, form with colored nodules and tannish orange aperture, AMNH 202746b;  $\times 2$ .

spectrum (Reeve, 1846)], numerous individual specimens of which were observed on the corals, has a more massive shell with fewer (9 per whorl) axial ribs that are more obtuse. These specimens, the largest of which examined by the second author measures 28+ mm in height, are white within and without, but the edge of the outer lip is tinged with greenish-yellow. The specimens are largely overgrown with calcareous algae and bryozoans (Figs. 2A, 2B). It should be noted that this species was previously placed in the synonymy of *Drupella cornus* Röding, 1798, see Cernohorsky (1969, pp. 304, 305, pl. 48, figs. 12, 12a, b, and figs. 14, 14a [fide Cernohorsky, 1978, p. 70]). H. A. Rehder (in Melville, 1980), however, notes that "*D. cornus*

is restricted to the Indian Ocean . . . [and] *D. elata* . . . is found in the Pacific from Indonesia eastwards." On morphological grounds, largely the color of the aperture (orange in *D. cornus*, white in *D. elata*), Rehder does not believe the two forms are conspecific, although he does not rule out the possibility that *D. elata* may prove to be a geographic subspecies of *D. cornus*. We follow Dr. Rehder in referring the western Pacific specimens of this complex to *D. elata* (Blainville).

The third muricacean gastropod observed preying on corals at Miyake-jima is the wide-ranging Indo-Pacific species, *Coralliophila violacea* (Kiener, 1836) [= *Murex neritoides* Gmelin, 1791, not Linné, 1767; = *C. diversi-*

*formis* (Kiener, 1836); = *C. squamulosa* (Reeve, 1846)]. This distinctive suctorial-feeding species is characterized by the dark violet aperture and whitish squamulose striate exterior (Cernohorsky, 1972, p. 131, pl. 37, fig. 5).

**Philippines:** The muricid snails found swarming on corals at Mactan Island are referable to *Drupella rugosa* (Born, 1778, p. 303) [= *D. concatenata* (Lamarck, 1822)]. These specimens (Figs. 3A, 3B), the largest of which measures 24.6 mm in height (mean height approximately 18 mm in a sample of 360 specimens), has a conspicuously nodular appearance. The body whorl is sculptured with 3 to 4 rows of prominent nodules, which are reduced to a single row on the penultimate whorl. The color varies considerably, ranging from creamish-white specimens to ones with dark brown or tannish nodules. The aperture and siphonal canal may be entirely white or a bright tannish-orange. Two specimens of *Drupella elata* (Blainville, 1832) were among the 348 specimens of *D. rugosa* collected in one of the sites sampled on Mactan Island. The larger specimen (AMNH catalogue no. 202766) measures 29.6 mm in height.

### Field observations

Although situated at more than 34° North latitude, Miyake-jima supports a surprisingly diverse tropical fauna (Ida and Moyer, 1974; Shepard and Moyer, 1980; Tribble and Randall, MS). Tribble and Randall (MS) identified 92 species of scleractinian corals representing 45 genera. These are widely scattered in small outcroppings, rather than as true coral reefs such as those typically found at tropical latitudes. Some relatively large *Acropora* patches are present in scattered locations around the island, the largest of which is located at Toga Bay on the southwest side of the island. This patch covers an area of approximately 1200 m<sup>2</sup>, and will hereafter be referred to as Toga Reef No. 1.

"Swarm 2" of *Drupella fragum* was first noted on a large platform of *Acropora* sp. (1.5 m in diameter) at Toga Bay, on the northwest side of Miyake-jima, in August, 1976. Recent evidence of gastropod predation was evident in the form of fresh, white, irregular notches and small

swarms of *D. fragum*, but when the entire platform was found dead and overgrown with algae in the Spring of 1977, it was not known whether it was killed by *D. fragum*, *Acanthaster planci* (which appeared on the island's corals in the winter of 1976-77; Moyer, 1978), or from siltation from construction near the bay followed by heavy rains.

A similar *Acropora* platform at Igaya Bay was used as a cleaning station by a juvenile labrid fish, *Thalassoma lutescens*, in 1978, and was photographed and repeatedly observed at that time (Fig. 4A). During September and October, 1978, a swarm of *D. fragum* appeared on this coral, which was subsequently totally destroyed, apparently by *Drupella* predation (Fig. 4B).

Accurate observations and measurements of *D. fragum* destruction were not possible until the autumn (September and October) of 1980, when one of us (JTM) was engaged in daily *Acanthaster* monitoring as part of a removal program. At this time, sizeable areas of freshly killed white *Acropora* spp. were discovered, with the area of destruction widening on a daily basis. Careful searches in and under the corals disclosed only swarms of *Drupella fragum*. During an evening dive, 17 September 1980, an infestation of several thousand *Drupella fragum* was found massed around the border between living and dead corals, devouring the polyps. The snails were bunched around and on top of each other in such numbers that it was impossible to estimate how many individuals were present. Between 20:25 h and 21:00 h, a total of about 1,500 were collected, 662 of which were kept and later deposited at AMNH (catalogue no. 203816). The remaining specimens were discarded. Hundreds of others fell through the coral branches and could not be recovered. Interestingly, all 12 AMNH specimens selected at random for radular study were found to be females. This swarm of *D. fragum* seemed to disperse as waters cooled in winter, however, an area of 35 m<sup>2</sup> of reef was destroyed by their predation during the two month period of observations (Fig. 5). No egg cases were observed on or under the corals, suggesting that the gastropods were swarming to feed. There was no noticeable evidence that the swarms were

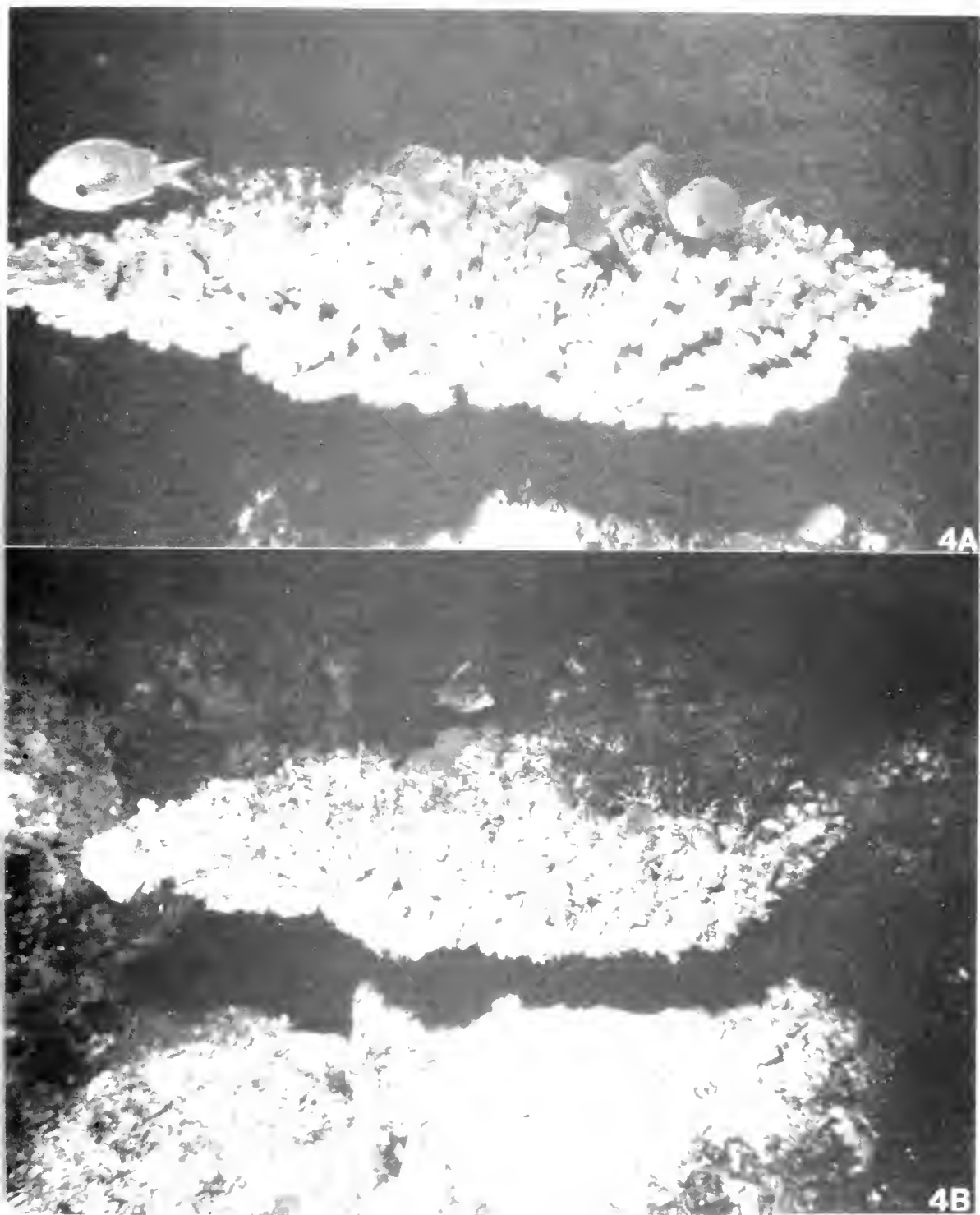


FIG. 4. A, Healthy *Aeropora* coral platform at Meppia, near Jervis Bay, with the nurse fish, *Thalassoma luteum* (Labridae), cleaning *Chromis flavo-oculatus* (Pomacentridae). B, Same *Aeropora* platform in 1981, but without nurse fish exposed with algae, after invasion of *Drupella fragilis*. Note that coral platform is in both photographs, even as unharmed by gastropod invasion.

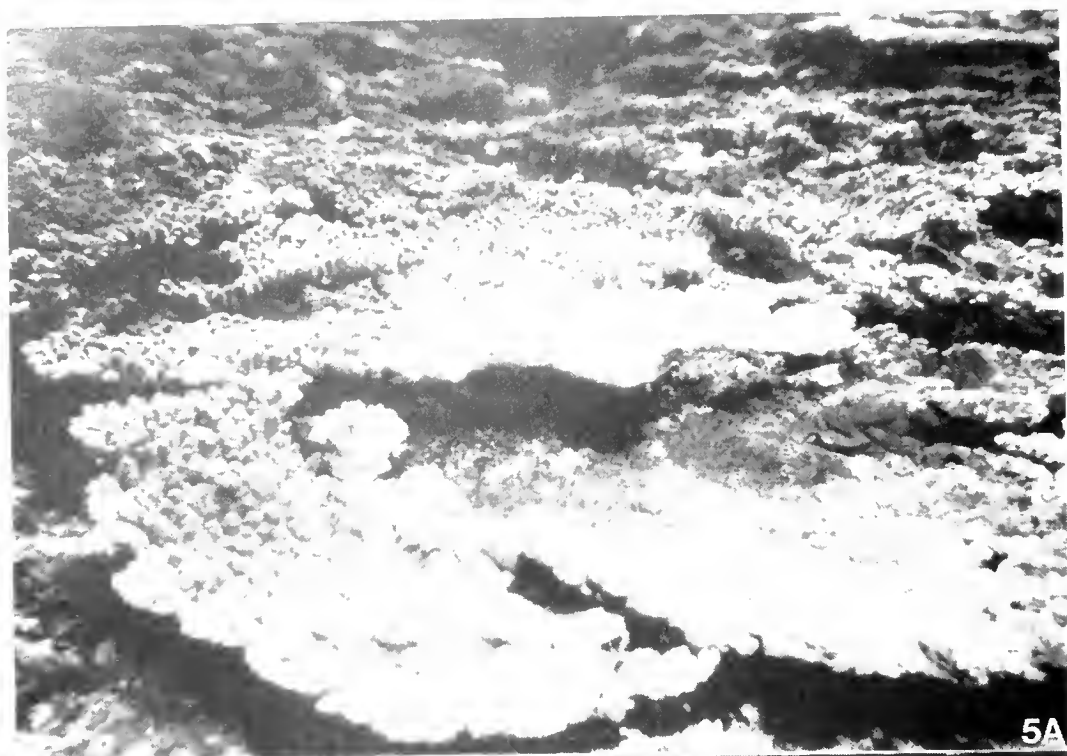


FIGURE 5  
A

Figure 1979, prior to *Drupella fragum* invasion; B, Toga Reef No. 1, Miyake-jima, 5C, (on opposite page) Dead reef at same location in October, 1981.



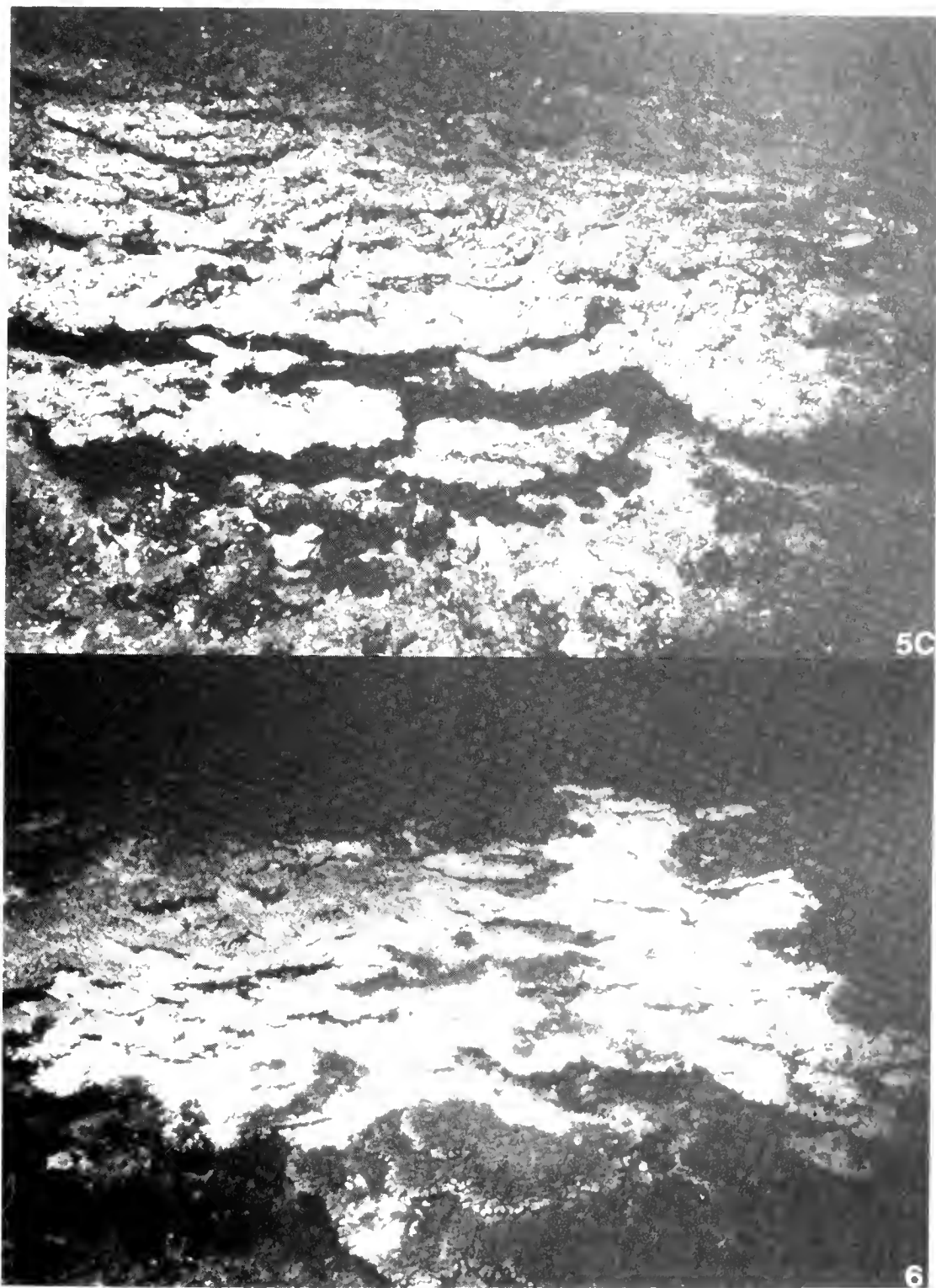


FIG. 6. Toga Reef No. 1, Miyake-jima, Japan, during *Drupella fragum* explosion, November, 1981. Note evidence of movement from left to right in photo, with fresh algal growth over earlier coral kill at the left of photo.

directly related to reproductive purposes, but an indirect relationship (intensive feeding either directly before or directly after the reproductive season) cannot be discounted.

A similar explosion of *D. fragum* was monitored at Toga Reef No. 1 throughout the month of November, 1981 (Fig. 6). During this period, a total of 17 m<sup>2</sup> of coral was destroyed. The combined damage observed during two months in 1980 and one month in 1981 amounted to more than 4% of the 1200 m<sup>2</sup> reef being destroyed by what was unquestionably predation by *D. fragum*. Between 1979 and 1981, approximately 35% of Toga Reef No. 1 was destroyed. Records from a carefully monitored *Acanthaster* removal program carried out in Toga Bay in 1980 and 1981 strongly suggest that *Drupella fragum* predation was responsible for most of the coral destruction at Toga Reef No. 1. *Acanthaster* were rarely seen at that reef, but were present in small numbers at Toga Reef No. 2 and, more commonly, at isolated patches deeper in the bay.

Surveys in November, 1981, at Igaya Bay, site of the first detection of *Drupella fragum* outbreaks in 1976, disclosed numerous patches of freshly killed *Acropora* spp., similar to those attributed to probable *Acanthaster* predation in 1978-1980. Close observation in and under the branches of such corals invariably disclosed clusters of *D. fragum* and numerous individuals of the much larger *D. elata* (Blainville, 1832). Relatively low numbers of *Acanthaster* were removed from Igaya Bay, in spite of intensive searches during the *Acanthaster* removal programs in 1979-1980. This fact, plus incidental observations of *D. fragum* outbreaks from 1976 to 1980 and the widespread occurrence of isolated patches of corals under *Drupella* attack in 1981 (when the first intensive searches for the muricids were attempted), suggest in retrospect that a large amount of the massive *Acropora* destruction at that site (perhaps as much as 50% or more) is attributable to population explosions of *Drupella fragum*.

Further to discover the important role of muricid predation at the onset of coral destruction at Miyake-jima resulted from (1) presence of moderate numbers of *Acanthaster planci* at various locations on the island and the perhaps

understandable assumption that fresh coral kill resulted from asteroid predation, and (2) the secretive behavior of *D. fragum*, which aggregate far back under coral branches by day, coming out at night to feed on coral polyps (Fig. 7). Observations in 1981 suggest that *D. fragum* are more active during the dark phases of the moon than around the full moon (more were visible on both night and day dives around the new moon than at the full moon, and more fresh coral kill was noted, although accurate measurements on a daily basis could not be obtained, due to the position of the study site on the windward side of the island). *D. fragum* also appeared to be negatively phototactic. Many dropped between the coral branches when caught in the flashlight beam or as the strobe flashed.

At Mactan Island, data on swarming by *Drupella rugosa* were collected from three different sites, two at Tambuli Beach (AMNH catalogue nos. 202763, 202764) and one at Malingin Beach (AMNH catalogue no. 202765), see Table 1. On Philippine reefs studied by the third author, these snails are usually found widely dispersed, in small groups or as individuals, and they apparently are restricted to shallow waters. Since April, 1980, it has been noted that at the Mactan study sites, *D. rugosa* has occurred on numerous occasions in higher densities, including swarms of up to 1500 individuals per .5 m<sup>2</sup>, comparable to swarms of *D. fragum* on *Acropora* corals at Miyake-jima (Fig. 8). Significant destruction of specific corals was noted in localized areas; however, massive reef destruction, such as reported above on the reefs at Miyake-jima, has not been observed. Grazing by swarms of *D. rugosa*, like *D. fragum*, is nocturnal, with observed predation to date limited to the Astrocoeniina, specifically, Acroporidae and Pocilloporidae. These corals, including the genera *Montipora*, *Acropora*, *Seriatopora* and *Pocillopora*, are all small polyped and branching or foliate in growth form (Table 2). For these commonly grazed corals, unlike the Japanese situation, predation appears random and incomplete, resulting in scattered patches of surviving corals in the grazed areas. Corals with larger polyps (greater than 1 mm) and massive growth forms are avoided and not subject to predation by these molluscs, either in

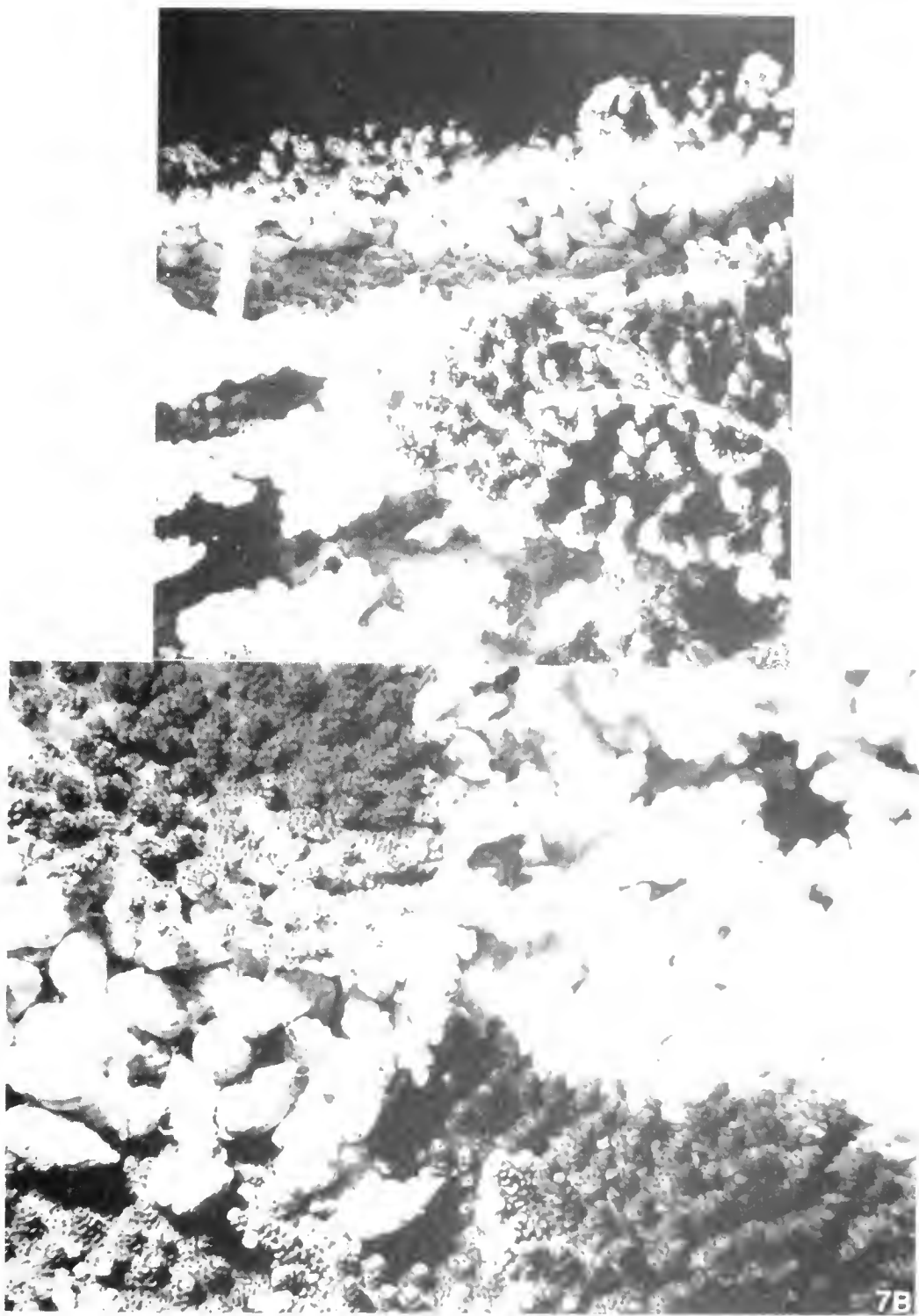


FIG. 7. A, Diurnal aggregation of *Drupella fragum* under *Acropora* sp. at Toga Reef No. 1, Miyake-jima, Japan, November, 1981; B, Nocturnal feeding of *Drupella fragum* on *Acropora* sp. at Toga Reef No. 1, Miyake-jima, Japan, November, 1981.

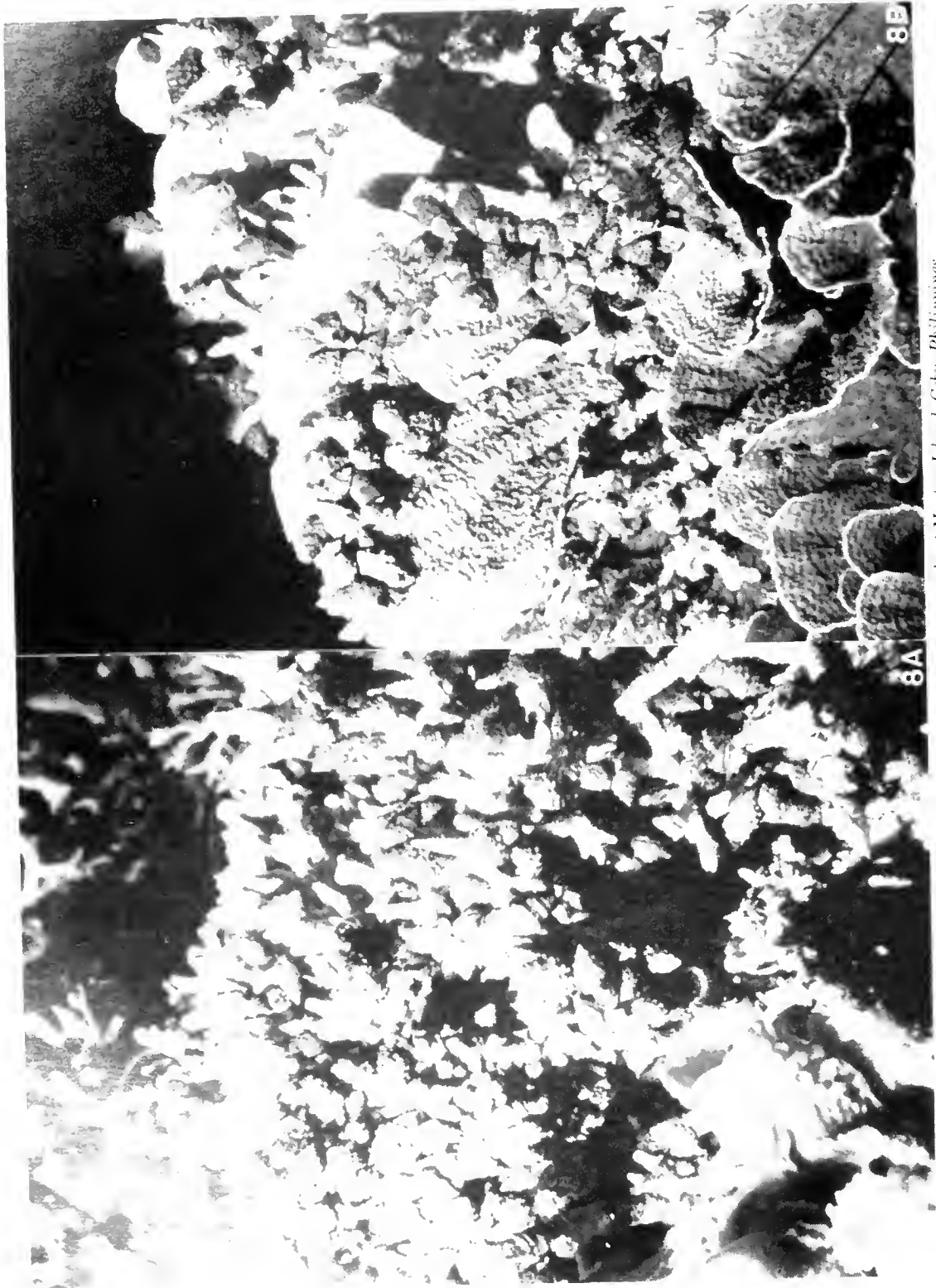


FIG. 8. A and B, Swarming of *Drupella rugosa* on corals at Mactan Island, Cebu, Philippines.

Table 1. Composition of dominant corals on Mactan Island study sites

Coral	Tambuli Beach	Malingin Beach
<i>Montipora</i>	71.9%	80%
<i>Porites</i>	9.4%	4.8%
<i>Acropora</i>	3.8%	1.4%
<i>Pavona</i>	2.1%	1.9%
<i>Galaxea</i>	1.9%	3.8%
<i>Avites</i>	1.7%	1.3%
<i>Pocillopora</i>	1.6%	.05%
<i>Avia</i>	1.4%	1.7%

Table 2. Grazing preferences of *Drupella rugosa* at Mactan Island

## Commonly Grazed Corals

<i>Montipora fruticosa</i>	<i>Acropora formosa</i>
<i>M. gracilis</i>	<i>A. tenuis</i>
<i>M. alveolatus</i>	<i>A. florida</i>
<i>M. ramosa</i>	<i>A. palifera</i>
<i>M. foliosa</i>	<i>A. robusta</i>
<i>M. prolifera</i>	<i>A. humilis</i>
<i>Seriopora hystrix</i>	

## Moderately Grazed Corals

<i>Pocillopora verrucosa</i>	<i>Acropora hyacinthus</i>
<i>Seriopora caliendrum</i>	<i>A. millipora</i>

## Commonly Avoided Corals

<i>Montipora cactus</i>	<i>Galaxea</i>
<i>M. verrucosa</i>	<i>Pavona</i>
<i>Porites</i>	<i>Merulina</i>
<i>Avia</i>	<i>Euphyllia</i>
<i>Avites</i>	<i>Hydnophora</i>
<i>Platygyra</i>	<i>Pectinia</i>
<i>Leptastrea</i>	<i>Lobophyllia</i>
<i>Montipora</i>	<i>Symphylia</i>
<i>Syphastrea</i>	<i>Forgia</i>
<i>Cardenoseris</i>	<i>Polyphyllia</i>
<i>Celosseris</i>	<i>Cycloseris</i>
<i>Leptastrea</i>	<i>Echinopora</i>

warms or as individuals (Table 2). Contrary to the report by Demond (1957), which found *Drupella elata* "most frequently on *Porites* sp.", and that of Taylor (1980) of *D. rugosa* predation on *Porites* colonies, *Porites* spp. appear to be entirely avoided by *Drupella rugosa* in the Philippines. In addition, several highly tuberculate

(course surface projections) species of the most commonly grazed genus, *Montipora*, are also entirely avoided, suggesting a degree of host selection.

## Discussion

Robertson (1970) reported that species of *Drupella* are known to be associated with scleractinian corals, and Fankboner (in Robertson, 1970) described feeding of *Drupella cornus* (Röding, 1798) on polyps of stony corals. Taylor (1976, pp. 178, 185; 1978, pp. 95, 98) records that *Drupella cornus* and *D. rugosa* (Born, 1778) feed on coral polyps. The literature, however, suggests that not all the species of *Drupella*, at least at the presently recognized generic allocations, may be obligate coral associates (Cernohorsky, 1969, p. 304; Robertson, 1970; Taylor, 1978, p. 99). This is further suggested by the fact that four individuals of *D. elata* (Blainville, 1832) appeared on a species of *Goniopora* (Poritidae) within a week after 6 of 8 parasitic muricean gastropods, *Coralliophila violacea* (Kiener, 1836), were removed from the coral at Miyake-jima. The coralliophilids had been observed regularly over a period of six months in the same *Goniopora* sp. with no appearance of muricid predators during that period (M. Zaiser, pers. comm.). It is tempting to speculate that the parasitic relationship of *C. violacea* and its host may include some elements of mutualism. Taylor (1978, p. 99), however, found on Gan Island, Addu Atoll, Maldives, that *Drupella cornus* and *Coralliophila violacea* occur mostly on different species of stony corals, and, as noted above, *Drupella rugosa* avoids Poritidae in the Philippines, but such avoidance is not necessarily the case elsewhere (Taylor, 1980). The possibility of competitive interactions between *C. violacea* and *Drupella* spp. is currently under investigation by the senior author.

Our information on the composition of living and grazed corals at the Mactan Island reef sites suggests a degree of host selection by *Drupella rugosa*, with specific preferences for *Montipora* and *Acropora* and an obvious avoidance of *Porites*, which is more common at Mactan than *Acropora* (Tables 1 and 2). The effect of such

prey-preference is similar to that reported for *Acanthaster planci* by Goreau, *et al.* (1972), and Glynn (1976). These studies revealed a parallel selection by *Acanthaster* for numerically common, fast growing species of *Acropora*, *Montipora*, *Pocillopora*, *Striatopora*, and *Stylophora*, as well as some faviids and fungiids. Other corals appeared to be resistant to *Acanthaster*, *e.g.* *Millepora*, *Heliopora*, *Goniopora*, and certain species of *Porites* and *Pocillopora* (Goreau, *et al.*, 1972). Under "normal" conditions on tropical reefs, such as those at Mactan, the results of selective predation both by *Acanthaster* and *Drupella* appear to be the same, *i.e.*, a periodic "weeding out" of the fast-growing, foliate species (particularly the very abundant *Montipora* at Mactan), providing space and settlement sites for other corals and thus increasing diversity over time. As discussed by Goreau, *et al.* (1972) for *Acanthaster* predation, there will be understandably different immediate and long term effects as far as diversity and coral cover are concerned, depending upon the intensity of predation. At Mactan, *Drupella rugosa* appears to represent an additional biological control (with *Acanthaster*) on the coral community structure. This seems to be characteristic on tropical reefs elsewhere. R. Randall (*pers. comm.*) reports that at Guam *Drupella* sp. feeds exclusively on *Pocillopora*. Entire *Pocillopora* colonies are destroyed, but destruction of large segments of the reef, such as that occasionally caused by *Acanthaster* population explosions, does not occur.

The situation in the warm temperate waters at Miyake-jima is quite different. As noted, true coral reefs do not occur there, although coral diversity is remarkable for such a high latitude. *Acropora* spp. are dominant and form large patches at certain localities, *e.g.* Toga Reefs Nos. 1 and 2. However, other corals are relatively scattered in isolated, small colonies on the bare substrate (Tribble and Randall, MS). Pacific fringing *Acropora* are preferred prey of *Drupella fragum*, and we have never seen evidence of *Drupella* feeding on other coral genera.

Why do *Drupella* population explosions

began to occur in about 1976 at one site on Miyake-jima and in 1980 at another site is a puzzling question. The senior author has worked on both sites since 1957, finding no evidence of widespread coral destruction until 1976. It may be more than a coincidence that heavy silting from construction programs near the study sites preceded each outbreak by from 2 to 4 years in both cases. Beginning in 1972 and continuing until 1974, large amounts of sand were pumped with seawater through a large sandpipe from the sandy interior of Igaya Bay to a filtering center on shore, where the sand was collected. The murky water, containing fine sediments, flowed back into the bay, settling over coral patches. Occasional breaks in the sandpipe added to this siltation. During the same period, a large pasture for dairy cattle was constructed on the volcanic mountain above the bay. Lumbering, followed by bulldozing to level the land, preceded the planting of cattle feed. Five dry river beds run into Igaya Bay, all of which pass through this recently constructed pasture. Heavy rains during the period of bulldozing flooded the rivers with muddy water and cut visibility in the bay (normally 15–40m) to less than 2 m on many occasions during this period. *Drupella* destruction was noted from 1976, four years after the beginning of both sand mining and pasture construction.

Similarly, in 1976 a road was constructed to Toga Bay for the purpose of development of a marine park featuring Toga Bay's two large coral patches (Toga Reef No. 1 and Toga Reef No. 2). Silting from this road into the bay began immediately, but increased greatly in 1978, when the road was paved and drainage ditches constructed to a point about 300 m above the bay. Erosion along the remaining 300 m of road since 1978 has been massive. *Drupella* destruction in Toga Bay first appeared in 1980, four years after the construction of the road and two years after severe siltation.

Although the relationship between massive siltation and population explosions of *Drupella fragum* at Miyake-jima must remain purely speculative at this time, it is of interest to consider the gastropod population explosions in the light of Birkeland's (in press) hypothesis relating



cycles of *Acanthaster planci* destruction with long periods of drought followed by heavy rains. Birkeland presents evidence to show that heavy rainfall following an extended dry season or drought results in great increases in nutrients, especially phosphorus, from terrestrial runoff into the shallow waters near shore, thus stimulating unusually lush blooms of phytoplankton. This increased food supply permits *Acanthaster* larvae to survive in much higher densities than under normal conditions, resulting in population explosions and extensive coral damage three years later, when the postlarvae reach maturity.

A similar phenomenon may account for the *Drupella fragum* explosions at Miyake-jima; heavy siltation from human activities accompanying typhoon or rainy season downpours, thus introducing nutrients into coastal waters. Many shallow water marine invertebrates experience outbreaks at irregular intervals (Coe, 1956), and such outbreaks have been related to terrestrial nutrient runoff (see Sutcliffe, 1972, 1973). J. B. Taylor (1975) identified 14 species of thaidid veligers (all four-lobed) in the plankton of Kaneohe Bay, Hawaii, including *Drupella elata* (as *D. cornus*). It is possible that *Drupella* larvae eat phytoplankton and that the heavily silted corals may be unable to consume these larvae in numbers sufficient to control their population. Of course, we recognize that this is pure conjecture, but we present it for the purpose of stimulating research on this intriguing problem.

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## SUCCINEA AVARA SAY FROM THE SOUTHERN GREAT PLAINS OF THE UNITED STATES

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### ABSTRACT

*Succinea avara* Say, 1824, was described from shells collected from the Northwest Territory. This study is of *S. avara* collected at 21 stations in four states of the Southern Great Plains Region of the United States. Shells and anatomical structures are described and illustrated; habitats of a selected representative series from the 21 stations are described.

### *Succinea avara* Say, 1824

- . 1824, p. 250; pl. 15, Fig. 6.  
———. Polkory, 1948, pp. 837-840;  
———. B. L. C., v. D.

Shells of *Succinea avara* represent only a few distinctive morphological and specific determinations

depend largely upon anatomical characteristics of the soft parts. It is questionable whether the anatomy of the soft parts as now identified with a species actually corresponds to the anatomy of the soft parts of the holotypes and paratypes which are known only from their shells. It is im-



possible to determine the exact location of the type locality when geographically it is designated only as being in a general area, as for *Succinea avara* Say, "Inhabits the Northwest Territory" (Say, 1824, p. 260). The succineas taken from a locality today may not be representative of the fauna existing fifty to a hundred or more years ago. Such are the problems concerning the identification of *S. avara* Say.

The shells of the holotype and paratypes of *Succinea avara*, Academy of Natural Science Philadelphia No. 59542, are small and probably immature.

#### Type description:

"*S. avara*. Shell suboval, pale reddish-yellow, subdisplanous, fragile, covered with an earthy crust; whorls three, minutely wrinkled; body whorl very large; spire small; aperture large, subovate, about two-thirds of the whole length of the shell. Length three-twentieths of an inch. Inhabits the North-west Territory. This small species of *Succinea* occurs in humid places very frequently under stones and near the water. The shell is always completely incrustured with a coating of earth. It may at once be distinguished from either the *ovalis* or of *campestris* by its very small size. Pl. 15, fig. 6." (Say, 1824, p. 260.)

Pilsbry (1948, pp. 837-840, Fig. 455 and Fig. 442, A, a, B, b, C, c, D) described what he considered to be *S. avara*. Fig. 442, B, b, are drawings of the reproductive system of a specimen from Warm Spring Canyon, Arizona, collected by Ferriss in 1909; C, c, are of a specimen from Hurricane Fault, Arizona.

The purpose of this paper is to describe shell and anatomical features, as well as habitats, of *Succinea avara* Say of the Southern Great Plains of the United States. Collections were made by Artie L. Metcalf and by me at 21 stations located in the western half of Texas, eastern and southern New Mexico, southern and northwestern Oklahoma and southwestern Kansas (Fig. 1).

Succineidae are generally regarded as being amphibious—living on wet ground, in woods, along shores, or appearing on the surface following a rainfall heavy enough to soak the ground. However, we have sometimes found



FIG. 1. Four-state map showing locations of the 21 collecting stations.

them in habitats far removed from wet areas.

At the stations where *S. avara* was obtained, the annual precipitation ranges from about 9 to 44 inches. All stations are subjected to periods of from 3 to 5 months in which the precipitation is less than an inch per month (Yearbook of Agriculture, 1941). *S. avara* included in this study were taken in early spring, summer, and early winter months during which time the snails were either active or aestivating. They were found in damp places under rocks, logs, boards or dead stems of *Yucca* sp. The following are the locations of the 21 collecting sites and descriptions of habitats of a selected representative series of ten of those sites. The field number designations and descriptions of habitats are by Artie L. Metcalf. My field numbers, enclosed in parentheses, serve as a reference to my records. Sites of my collections are indicated by my field numbers and the descriptions of such habitats are mine.

#### Stations

1. Field No. ALM 968 (DSF 402); 30 June, 1969, along the Cimarron River, along New Mexico Rd. 325; 7.5 mi W of its junction with New Mexico Rd. 370, Union County, New Mexico. Altitude: 5,250 ft. above mean tide (AMT). Annual precipitation about 17". Habitat: under logs on moist floodplain of the river and also under rocks on adjacent hillside.

2. Field No. ALM 1058 (DSF 412); 30 July, 1970; 2.5 mi N of Mt. Dora, Union County, New Mexico.

Field No. ALM 1060 (DSF 411); 31 July, 1970; valley of North Canadian River, 0.1 mi N of bridge over river on New Mexico Rd. 370, about 22 mi N NW of Clayton (S 33, T 29 N, R 52 W), Union County, New Mexico.

4. Field No. ALM 673, (DSF 342); 8 May, 1966; 5 mi SE of Rincon; HWY 1-25 at junction with Engle Road, Dona Ana County, New Mexico. Altitude: 4370 ft. AMT. Annual precipitation about 9.5". The locality is in Jornada del Muerto—a basin between two mountain ranges. Habitat: *Succinea arara* were aestivating on dead stems of *Yucca elata* Engelm. growing in a "tobosa grass swale" where the predominant plant is tobosa grass, *Hilaria mutica* (Buckl.) Benth. The snails were found on the side of the dead *Yucca* stems lying on the ground where there was a trace of moisture.

5. Field No. ALM 948 (DSF 398); 19 November, 1968; valley of Tularosa River and falls, 0.5 mi SW of bridge over Tularosa River, U.S. Hwy 70; 8.5 mi SW of Tularosa (NW ¼, SW ¼, S 32, T 13 S, R 11 E), Otero County, New Mexico.

6. Field No. ALM 946 (DSF 397); 19 November, 1968; Mescalero Indian Reservation, Valley of the Tularosa River, 1.05 mi S of Tularosa Spring (SW ¼, SW ¼, S 7, T 14 S, R 13 E), Otero County, New Mexico.

7. Field No. ALM 998 (DSF 407); 11 October, 1969, and 19 September, 1970; junction of Peñasco and Cox Canyons (SW ¼, S 3, T 17 S, R 13 E), Otero County, New Mexico. Altitude: 7200' AMT. Annual precipitation about 22". Habitat: grassy, riparian meadow where the Peñasco River is about 5 ft. wide. The canyon wall is wooded with predominantly Ponderosa pine.

8. Field No. (DSF 492); collected by Artie Metcalf 23 September, 1978; east-central part of Nash Draw Basin (center of S 15, T 22 S, R 30 E), 20 mi E of Carlsbad, Eddy County, New Mexico.

9. Field No. ALM 670; 8 February, 1966, and DSF 339, 7 May, 1966; Franklin Mountains (S 27, T 28 S, R 4 E), about 5 mi NE Canutille, El Paso County, Texas. Altitude: 4900 ft. AMT. Annual precipitation about 9". Habitat: under dead *Diospyron* sp. and under moist limestone rocks. A light rainfall which occurred the first of May resulted in certain areas being relatively moist.

10. Field No. ALM 1396 (DSF 426); 9 August, 1972; 0.6 mi SW of Dalhart on southeast side of U.S. Hwy 54 and bordering Rita Blanca Creek, Hartley County, Texas.

11. Field No. ALM 1283 (DSF 418); 19 June, 1971; 2.3 mi W Channing, south side of Texas Farm Rd. 767, Hartley County, Texas.

12. (DSF 389); collected by Artie Metcalf 23 August, 1968; flood plain of Wolf Creek, 1 mi E of dam on Lake George, O. J. Neff County, Texas.

13. (DSF 389); collected by Artie Metcalf 23 August, 1968; south shore of Lake Fryer, Ochiltree County, Texas. Altitude: 2650 ft. AMT. Annual precipitation about 16.2". Habitat: coarse limestone below scarp in Ogallala Formation.

14. (DSF 389); collected by Artie Metcalf 13 September, 1968; south shore of Lake Fryer, Ochiltree County, Texas. Altitude: 2650 ft. AMT. Annual precipitation about 16.2". Habitat: coarse limestone below scarp in Ogallala Formation.

15. Field No. ALM 1801 (DSF 476); 20 March, 1977; 9 mi ENE or 6.6 mi W of junction of Ranch Rd. 2084 (to Christoval) with Texas Hwy 29, S side of Texas Hwy 29, Schleicher County, Texas.

16. Field No. ALM 1451 (DSF 430); 16 April, 1973; east side of conical hill immediately E of old Fort Lancaster; N of U.S. Hwy 290, Pecos County, Texas. Altitude: 2075 ft. AMT. Annual precipitation about 19". Habitat: under limestone rocks on E side of conical hill. The vegetation consists of sparse grass and low xeric shrubs.

17. Field No. ALM 1458 (DSF 428); 18 April, 1973; under limestone rocks opposite Judge Roy Bean Visitor Center, Langtry, Val Verde County, Texas.

18. Field No. DSF 422; 14 July, 1972; Buffalo Bayou, Texas Hwy 6, 1 mi S of junction with HWY 1-10, near Addicks, Harris County, Texas. Altitude: 50 ft. AMT. Annual precipitation about 44". Habitat: *Succinea arara* found aestivating on a trunk of a pecan tree up to 7' above ground level and on a fence rail 5' above ground level. The ground vegetation comprised nettles and grasses which may have been too dense for the succineas; therefore, they sought more open areas.

19. Field No. DSF 387, 28 July, 1968, and 17 July, 1972; west bank of a bay of Lake Texoma, University of Oklahoma Biology Station, 2 mi E of Willis and Oklahoma State HWY 99, Marshall County, Oklahoma. Altitude: about 500 ft. AMT. Annual precipitation about 38". Habitat: the snails were aestivating under boards and logs lying on the unshaded bank of the lake; temperature at time of collection, 95°F.

20. Field No. ALM 1066 (DSF 414); 1 August, 1970; 6 mi S Turpin; 1½ mi N of Beaver Creek, Beaver County, Oklahoma. Altitude: 2600 ft. above AMT. Annual precipitation about 18". Habitat: under stones of bluff of Ogallala Formation. The area is a short grass prairie with *Yucca glauca* Nutt.

21. Field No. ALM 1559 (DSF 442); 1974; Point of Rocks, an escarpment of Ogallala Formation, 3 mi W of Kansas Hwy 27 on N side of Cimarron River, Morton County, Kansas. Annual precipitation about 16.2". Habitat: most of the *Succinea arara* were under a single large stone lying at base of scarp. *Yucca glauca* Nutt. and *Rhus trilobata* Nutt. were common plants. Grama grass and annual ragweed were abundant.

*The Shell:* Shell is conically-ovate, imperforate, amber, somewhat glossy, translucent, usually encrusted with grains of sand or soil. Composed of 2½ to 3¾ whorls, the shell attains a height of 12.6 mm and a width of 6.6 mm (Table 1). Whorls inflated, sharply incised, increasing rapidly in size from the knoblike nuclear whorl to the large, inflated body whorl. Aperture ovate, ranging from 47.6% to 77.7% of the height of the largest shells obtained at the 21 stations, bounded by a sharp peristome which

TABLE 1. Dimensions of shells of *Succinea avara* Say of selected ten of the twenty-one collecting sites. The measurements are of the three largest shells of each locality. Ratios of measurements are listed in the last four columns.

	No. of Whorls	Height	Width	Width Height	Height of Aperture	Width of Aperture	H. Ap. H. Shell	W. Ap. W. Shell	W. Ap. H. Shell
<b>Station #1</b>									
Union Co., NM	3 1/4	12.6 mm	5.45 mm	4.32	6.0 mm	4.7 mm	0.40	0.43	0.71
30 June, 1969	3 1/4	10.3	6.3	4.77	7.3	4.4	0.60	0.60	0.66
	3 1/4	10.0	5.8	4.60	6.11	4.1	0.41	0.40	0.62
Range (23 shells)	3 3/4 - 3 1/2	6.0 - 12.6	3.3 - 6.3	4.32 - 4.68	3.9 - 8.15	2.7 - 4.4	0.40 - 0.60	0.40 - 0.60	0.62 - 0.71
Median		9.10	5.15	4.54	6.05	4.05	0.54	0.41	0.67
<b>Station #4</b>									
Dona Ana Co., NM	3 1/4	12.3 mm	6.6 mm	4.34	7.0 mm	4.7 mm	0.60	0.42	0.71
8 May, 1966	3 1/2	11.3	5.9	4.52	6.2	4.1	0.44	0.41	0.67
	3 1/4	10.9	5.9	4.41	6.2	4.15	0.60	0.40	0.66
Range (29 shells)	3 - 3 1/2	6.65 - 12.3	3.7 - 6.6	4.14 - 4.64	4.4 - 7.0	2.5 - 4.7	0.41 - 0.64	0.40 - 0.40	0.66 - 0.71
Median		8.9	5.25	4.53	5.44	3.75	0.54	0.40	0.67
<b>Station #7</b>									
Otero Co., NM	3 1/2	9.7 mm	5.2 mm	4.56	5.65 mm	3.8 mm	0.52	0.40	0.67
11 October, 1964	3 1/2	9.6	5.55	4.57	6.2	4.3	0.64	0.74	0.65
	3 3/4	8.9	4.9	4.50	6.1	3.9	0.64	0.59	0.69
Range (39 shells)	2 1/2 - 3 3/4	4.15 - 9.7	2.55 - 5.55	4.30 - 4.44	2.9 - 6.2	2.1 - 4.3	0.41 - 0.70	0.40 - 0.74	0.61 - 0.71
Median		6.90	3.95	4.67	4.55	3.0	0.62	0.44	0.67
<b>Station #9</b>									
El Paso Co., TX	3 1/4	13.1 mm	6.3 mm	4.72	6.7 mm	4.2 mm	0.51	0.40	0.66
8 Feb.: 7 May, 1966	3 1/2	11.7	6.0	4.51	6.1	3.4	0.42	0.40	0.66
	3 1/4	13.7	6.8	4.72	6.8	3.9	0.42	0.42	0.64
Range (58 shells)	2 1/2 - 3 1/2	4.2 - 13.1	2.5 - 6.3	4.44 - 4.72	2.7 - 6.75	1.95 - 4.2	0.42 - 0.70	0.42 - 0.42	0.64 - 0.66
Median		8.25	4.35	4.67	4.65	3.2	0.62	0.42	0.66
<b>Station #13</b>									
Schiltree Co., TX	3 1/2	11.46 mm	5.6 mm	4.41	6.57 mm	4.51 mm	0.51	0.43	0.64
23 August, 1968	3 3/4	11.20	6.01	4.40	6.46	3.95	0.75	0.52	0.62
	3 1/2	11.15	6.1	4.60	6.6	4.2	0.62	0.59	0.66
Range (51 shells)	3 - 3 3/4	6.25 - 11.4	3.65 - 6.10	4.41 - 4.63	4.0 - 6.65	2.4 - 4.51	0.57 - 0.74	0.42 - 0.59	0.61 - 0.66
Median		9.50	5.2	4.53	5.91	3.39	0.64	0.40	0.67
<b>Station #16</b>									
Wecos Co., TX	3 1/4	9.5 mm	5.1 mm	4.30	5.5 mm	3.65 mm	0.40	0.41	0.66
16 April, 1973	3	7.8	3.64	4.42	4.58	2.75	0.63	0.41	0.64
	3	7.05	4.70	4.44	4.15	2.81	0.56	0.59	0.72
Range (16 shells)	2 1/2 - 3 1/4	5.0 - 9.5	2.70 - 5.10	4.42 - 4.64	3.85 - 4.6	1.95 - 3.65	0.47 - 0.63	0.40 - 0.59	0.61 - 0.72
Median		6.65	3.70	4.61	4.0	2.65	0.630	0.70	0.41
<b>Station #18</b>									
Larris Co., TX	3	7.2 mm	4.6 mm	4.38	5.0 mm	3.4 mm	0.77	0.50	0.67
14 July, 1972	3	7.0	4.3	4.14	4.1	3.2	0.75	0.44	0.67
	3	7.0	3.5	4.4	4.0	2.6	0.60	0.73	0.67
Range (15 shells)	2 1/2 - 3	4.5 - 7.2	2.3 - 4.6	4.1 - 4.64	3.2 - 4.1	2.1 - 3.4	0.61 - 0.77	0.40 - 0.73	0.47 - 0.67
Median		5.4	3.4	4.67	3.6	2.6	0.70	0.70	0.44
<b>Station #19</b>									
Marshall Co., W	3	8.6 mm	6.1 mm	4.12	7.1 mm	4.5 mm	0.54	0.40	0.66
28 July, 1968	3	8.6	5.3	4.14	6.1	4.1	0.74	0.40	0.66
	3	8.1	5.1	4.24	6.2	3.6	0.74	0.40	0.66
Range (22 shells)	2 1/2 - 3	5.4 - 8.6	2.8 - 6.1	4.12 - 4.24	4.1 - 7.1	3.1 - 4.1	0.63 - 0.74	0.40 - 0.40	0.66 - 0.66
Median		6.6	4.1	4.4	4.1	3.2	0.74	0.40	0.66
<b>Station #19</b>									
Marshall Co., W	3 1/4	8.2 mm	5.6 mm	4.50	6.6 mm	4.2 mm	0.64	0.40	0.66
17 July, 1968	3	8.6	5.3	4.14	6.1	4.1	0.74	0.40	0.66
	3	8.5	5.4	4.23	6.2	4.1	0.74	0.40	0.66
Range (16 shells)	2 1/2 - 3 1/4	4.5 - 8.2	2.8 - 5.6	4.12 - 4.50	4.1 - 6.6	3.1 - 4.2	0.63 - 0.74	0.40 - 0.40	0.66 - 0.66
Median		6.1	5.0	4.63	4.6	3.7	0.74	0.40	0.66
<b>Station #20</b>									
Leaver Co., W	3 1/4	8.1 mm	5.6 mm	4.20	6.6 mm	4.1 mm	0.63	0.40	0.64
1 August, 1970	3 1/2	8.9	4.7	4.25	6.1	3.6	0.63	0.44	0.67
	3 1/2	8.0	4.4	4.11	4.6	3.5	0.74	0.53	0.67
Range (17 shells)	3 - 3 1/2	5.25 - 8.9	3.17 - 5.6	4.11 - 4.25	3.6 - 6.1	2.6 - 3.6	0.63 - 0.74	0.40 - 0.53	0.66 - 0.67
Median		7.10	3.9	4.63	4.4	3.1	0.70	0.40	0.67
<b>Station #21</b>									
Orton Co., W	1	1.1 mm	0.7 mm	4.1	1.1 mm	1.1 mm	0.40	0.40	0.66
1974	1/4	0.7	0.4	4.1	0.7	0.7	0.60	0.40	0.66
	1/4	0.3	0.2	4.1	0.3	0.3	0.60	0.40	0.66
Range (1 shell)	1 - 1 1/4	0.7 - 1.1	0.4 - 0.7	4.1 - 4.1	0.7 - 1.1	0.7 - 1.1	0.60 - 0.60	0.40 - 0.40	0.66 - 0.66
Median		0.2	0.2	4.1	0.2	0.2	0.60	0.40	0.66

continues over the body whorl as a thin callus. Columella is gently curved (Fig. 2). Surface of

the nuclear whorl appears to be, at high magnification, malleated. Surface of the remaining

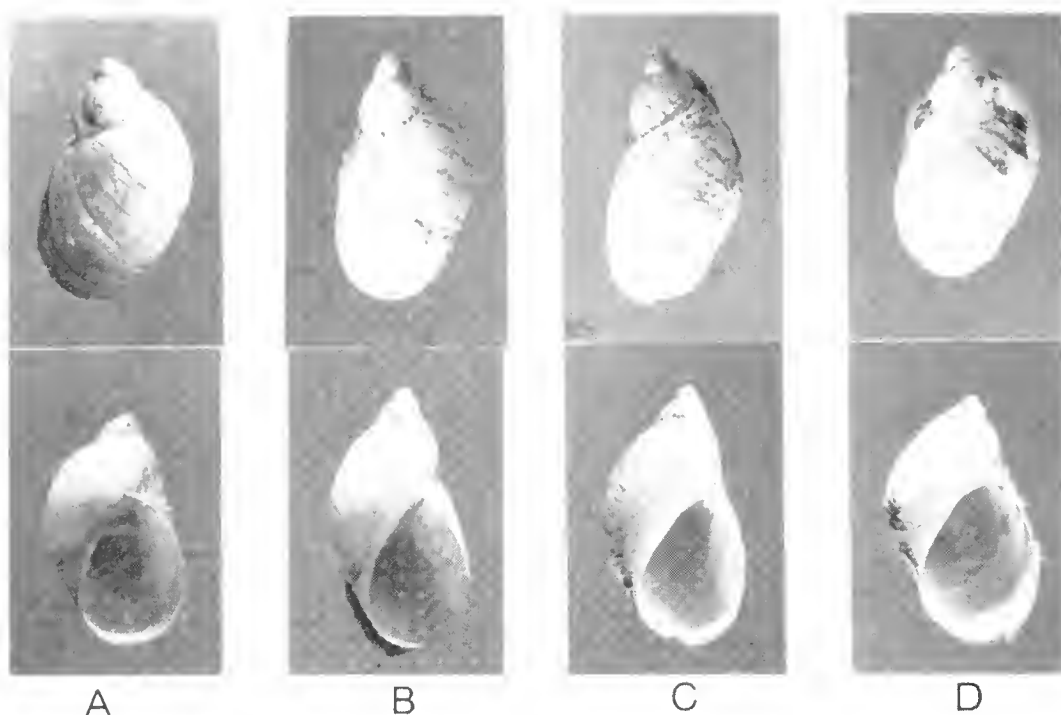


FIG. 2. Shells of *Succinea avara* Say of four collecting stations: **A**, Station 19, Marshall County, Oklahoma (Height 8.5 mm); **B**, Station 11, Hartley County, Texas (Height 11.1 mm); **C**, Station 13, Ochiltree County, Texas (Height 11.2 mm); **D**, Station 1, Union County, New Mexico (Height 10.5 mm).

whorls are marked with striae, fine on the penultimate whorl, becoming heavier and coarser producing a rough appearance on the ultimate whorl, especially near the aperture (Fig. 2).

**Body and Mantle Surfaces:** Surface of translucent, gray-white body is smooth; low tubercles may be observed on head region. On either side of the lower lateral body wall a suprapedal groove, paralleled by a shallow pedal groove, extends from the labial palp to the posterior tip of the body. Lateral body wall incised by shallow vertical grooves which extend to the pedal groove, resulting in a scalloped edge. Genital aperture elongate-crescent, about 0.7 mm in length, surrounded by a white, tumid lip, and situated on the anterior right-hand side of the body.

The bodies of *Succinea avara* of the geographical region included in this study are generally so lightly pigmented that it is difficult to recognize any distinct pattern. When intense enough to be discerned, pigmentation is seen to

form a pair of median bands on the anterior-most portion of the head. Just anterior to the superior (posterior) tentacles these bands fuse and expand to form a triangle. From this, at level of the tentacles, a single band extends to where the mantle attaches to the body. On the anterior portion of the head each of the two median bands is flanked laterally by a not very distinct band which extends to the base of the tentacles. Blotches of pigment on the tentacles form, at the base of each, a band which parallels the median band to the edge of the mantle. Also scattered flecks of pigment are to be noted. On either lateral body wall a faint band of flecks of pigment may run above and parallel to the suprapedal groove. The sole of the foot exhibits faint longitudinal bands of pigment.

Bands of pigment extend from the mantle collar across the mantle surface, coalesce as they approach the nephridium. Pigmentation in the form of a fine line outlines the anterior margin of the nephridium, diffuses over its surface, and,

as a heavier band, outlines its posterior margin. The nephridium is white.

**Reproductive System:** The stout penis and epiphallus fill the thin, translucent, non-pigmented or lightly flecked, penial sheath. Junctionure of epiphallus and penis is marked by a constriction (Fig. 3A). Epiphallus and penis may be contained entirely within the sheath (Fig. 3B) or the epiphallus and the distal portion of the penis may extend through the distally open-ended sheath (Fig. 3B). Because the thin sheath tends to cling to the penis, it is difficult to note that it is open-ended. Such variations occur within any of the populations included in this study. The vas

deferens enters the penial sheath near its distal end, emerges from the sheath as it enters the epiphallus terminally (Fig. 3A, B). The broad, stout penial retractor muscle attaches to the distal end of the epiphallus (Fig. 3A, B).

Prostate gland, globular, composed of small acini, enclosed within a very thin, finely peppered sheath, is approximately one-third the size of the albumin gland. Albumin gland, generally triangular, composed of small acini, is enclosed within a very thin, finely peppered sheath. Hermaphroditic duct may be slightly or moderately pigmented. Lobes of the bilobed seminal vesicles, unequal in length, are generally narrow, elongate, and lightly to moderately pigmented. Junctionure of uterus and oviduct is marked by a slight constriction. Spermathecal duct is broad at its base where it enters the uterus (Fig. 3A, B).

**Radula and Jaw:** Structure of the radula of *Succinea avara* exhibits characteristics of the genus. Number of rows of teeth range from about 70 to 90. Formulae of representative rows of teeth are to be noted in Table 2. Ratio of laterals to marginals approaches 1:1 as found to be true of *S. ovalis* Say (Franzen, 1959, Table II) and of *S. vaginacontorta* Lee (Franzen, 1971, Table II).

Structures of representative teeth are illustrated in Fig. 4A. The central tooth has a long, pointed mesocone which equals or exceeds

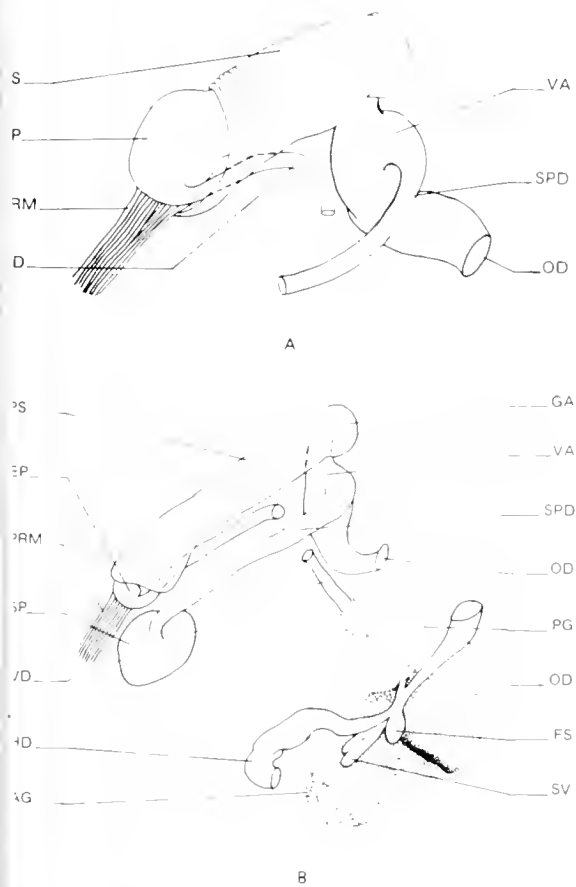


FIG. 3. Reproductive organs of *Succinea avara* Say. PS, penial sheath; EP, epiphallus; PRM, penial retractor muscle; VD, vas deferens; VA, vagina; SPD, spermathecal duct; OD, oviduct; SP, spermatheca; HD, hermaphroditic duct; AG, albumin gland; GA, genital atrium; PG, prostate gland; FS, fertilization sac; SV, seminal vesicle.

TABLE 2. Formulae of representative rows of teeth of radulae of *Succinea avara* Say.

STATION	No. of Rows of Teeth	Row					
		M	L	C	L	M	
No. 402	79	14	8	11	1	13	11
		31	10	9	1	10	10
		40		1	15	6	
		41		1	15	6	
		62		1	13	6	
No. 418	70	50	4	18	1	18	5
No. 425 (Slide 2)		24	2	13	1	11	10
		32	5	14	1	12	1
		49	5	12	1	16	5
No. 390		71	12	4	1	11	11
			13	3	1	12	11

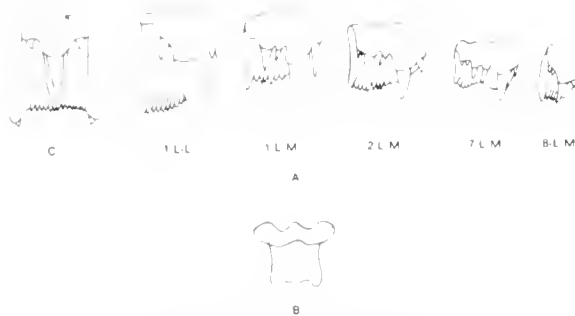


FIG. 4. A, Representative radula teeth of *Succinea avara* Say. C, central tooth; 1-L-L, first left lateral; 1-L-M, first left marginal; 2-L-M, second left marginal; 7-L-M, seventh left marginal; 8-L-M, eighth left marginal. B, A jaw of *Succinea avara* Say.

length of the basal plate; mesocone is flanked on either side by a small ectocone. Laterals have a long, sharply pointed mesocone which, generally, exceeds length of the basal plate; there is a single smaller ectocone; endocone is generally wanting. Differentiation between laterals and marginals is not always sharply defined; frequently an endocone is present on the outermost one to three laterals. There may be on either side of a lateral with a split ectocone a tooth with an undivided ectocone. Marginals are characterized by a short endocone, a long, sharply pointed mesocone, and an ectocone which is divided into two, three or four cusps. In *S. ovalis* and *S. vaginacontorta* the three small cusps of the ectocone are short and almost equal in size. In *S. avara* the two medial-most cusps of the ectocone are long; the outermost cusps are minute (Fig. 4A). The basal plates of the marginals are as in *S. ovalis* Say (Franzen, 1959, Fig. 3) and as in *S. vaginacontorta* Lee (Franzen, 1971, Fig. 3). They are not long and tapering as in the genus *Oryloma* (Franzen, 1963, Fig. 1) nor as short and broad as in the genus *Catinella* (Quick, 1933, Fig. 4); (Franzen, 1979, Fig. 3).

The amber-colored jaw is illustrated in Fig. 4B. Anteriorly the collar has a pointed median fold and posteriorly a rounded indentation. The posterior margin of the basal plate has a pointed median fold flanked on either side by a rounded boss.

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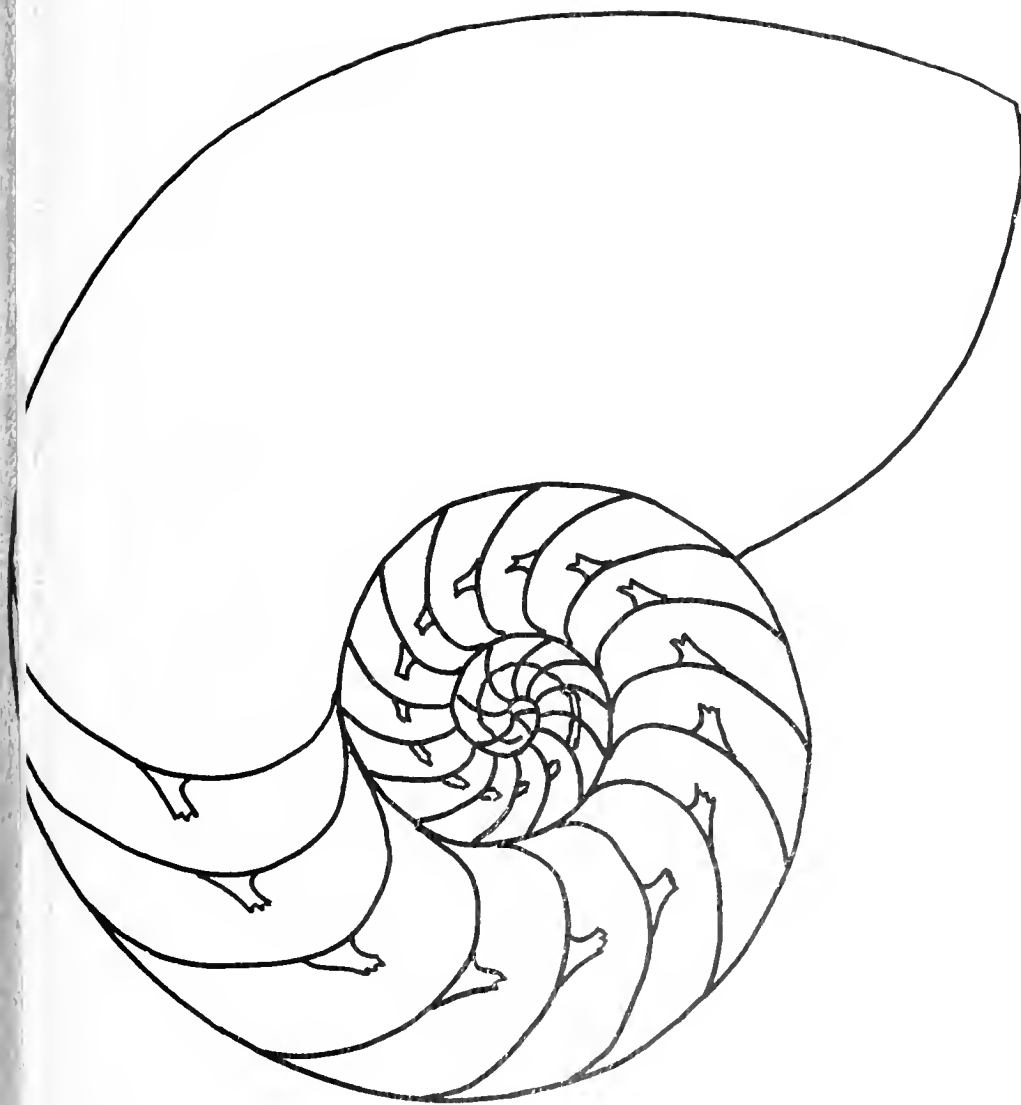
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## CIPANGOPALUDINA CHINENSIS (GASTROPODA: VIVIPARIDAE) IN NORTH AMERICA, REVIEW AND UPDATE

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### ABSTRACT

*The Asian freshwater viviparid snail, Cipangopaludina chinensis (Gray), was introduced into North America in the 1890's. The species has spread across the United States and southern Canada and is well-established in the northeastern U.S. Connecticut populations are limited to lakes and ponds of medium-hard to hard waters of calcium levels in excess of 5 ppm. The shell growth of C. chinensis is allometric with the young snails having a lower shell height to shell width ratio than the adults. The growth patterns and radular cusp number of the typical chinensis and the japonicus morph differ from each other. A literature review notes the five-year life span, diatom diet, the importance of quality food sources in regulating population parameters, and the role of C. chinensis as a possible host for Asian helminths.*

The Asian freshwater prosobranch snail *Cipangopaludina chinensis* (Gray, 1834) (Synonym; *Viriparus chinensis malleatus* (Reeve, 1863)) was first introduced into North America in the 1890's (Abbott, 1950). Since then, malacologists have been documenting the spread of populations of *C. chinensis*. This species has become well-established in parts of North America and it is time to review the known North American biogeography, ecology and natural history of *C. chinensis*. This paper will also add information on the snail's environmental preferences, radular structure, and shell growth pattern.

Dundee (1974) and Clarke (1978) have synonymized *C. japonicus* (von Martens, 1861), with *C. chinensis*. Clench & Fuller (1965) believed that the two were different species with individuals of *C. japonicus* having more elongate shells (higher height/width ratios) with smaller apical angles than *C. chinensis*. Morphological intergrades exist (Clench & Fuller, 1965), indicating either hybrid populations of two species, or different morphological types within one species. Apparently Clarke (1978) has decided upon the latter explanation but extensive com-

parative morphological and immunological studies have not been published. Therefore, this paper will differentiate, when possible, between typical *C. chinensis* and *C. japonicus* by indicating "japonicus" forms as "japonicus" morphs, thereby cautiously following a middle ground that may easily be assimilated into a final resolution of the problem.

*C. chinensis* was first brought to North America in the early 1890's by sailors returning from Yokohama, Japan. The sailors sold the snails to merchandize dealers in San Francisco's chinatown (Wood, 1892a, 1892b; Stearns, 1901). Although Wood called these specimens "*japonica*", the snails were actually *C. chinensis*, the first introduced *japonicus* not being recorded until 1911 (Hannibal, 1911; see discussion in Clench & Fuller, 1965). A second west coast introduction was reported by Rev. G. W. Taylor who found "*japonica*" being sold in a Chinese market in Victoria, British Columbia (Anonymous, 1894). It is not known whether these snails were of the *japonicus* or the *chinensis* type (Clench & Fuller, 1965), and there has been no report of established Asian viviparid populations in British Columbia. Additional west coast

colonies have been reported from California and Washington (Clench & Fuller, 1965; Hanna, 1966; Branson, 1977).

Individuals of *C. chinensis* were first found on the east coast by W. Clench who collected specimens in Massachusetts from the Muddy River, a stream dividing Boston from Brookline. The snails may have been introduced when goldfish were added to the stream for mosquito larvae control (Johnson, 1915). Additional east coast colonies have been reported from Quebec, Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, North Carolina, and Florida (Johnson, 1916, 1918; Richards & Adams, 1929; Schmeck, 1942; Jacobson & Emerson, 1961; Clench & Fuller, 1965; Stanczykowska *et al.*, 1971; Perron & Probert, 1973; Bucci, 1974; Dundee, 1974; Clarke, 1978). Additional populations have recently been found in Connecticut (see below for details).

*C. chinensis* populations have also spread mid-continently in Ohio, Michigan, Wisconsin, Indiana, Minnesota, Arizona, Colorado, Texas,

Iowa, Oklahoma, and Utah (Teskey, 1954; Branson, 1959; Clench & Fuller, 1965; Huehner & Etges, 1971, 1972; Barnhart, 1978). Figure 1 is a map of all the recorded references to North American populations of *C. chinensis* north of Mexico (excluding Hawaii). This species is very well established on the northeast coast where it should now be considered as a permanent part of the freshwater molluscan fauna. The species is also becoming well entrenched in the St. Lawrence-Great Lakes drainage. It is also common on the west coast between San Francisco and Seattle. Additional colonies are scattered across the continent. The paucity of mid-continental colonies may reflect a lack of information but it should be noted that some reports of recent continental malacological surveys mention no colonies of *C. chinensis* (Harman & Berg, 1971; Clarke, 1973).

#### Connecticut Records

Over the past several summers I surveyed 215 aquatic sites in southern New England, especially Connecticut, for gastropods. Populations of typical *C. chinensis* have been found in seven

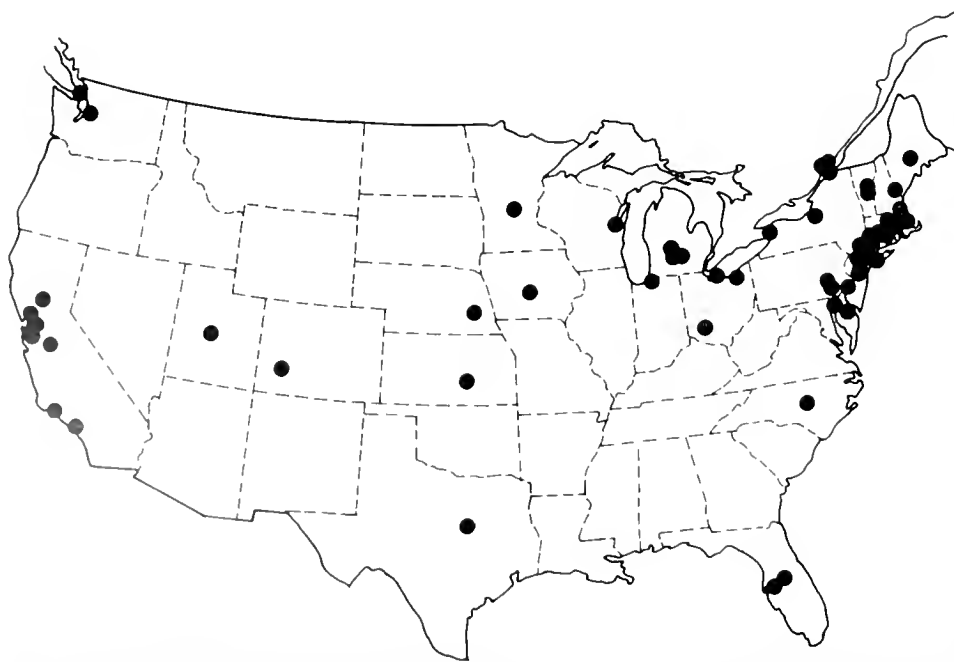


FIG. 1. 1982 distribution of *Cipangopaludina chinensis* (Gray). See text for references.

lakes and ponds in Connecticut and one lake in Vermont (Lake Fairlee, Thetford Center, previously reported in Clench & Fuller, 1965). A population of the *japonicus*-morph lives in one lake in Connecticut (Black Pond). Table 1 summarizes the physical/chemical data on the Connecticut sites. Methods of water chemical analysis have been described elsewhere (Jokinen, 1978).

Populations of *C. chinensis* were generally found in larger lakes or ponds with sandy to muddy sand substrates. The snails were either crawling on the substrate or on dock pilings. Even though several investigators have noted *C. chinensis* living in slower waters of streams (Schmeck, 1942; Stanczykowska *et al.*, 1971) all Connecticut sites were lentic.

Due to the fact that most of the bedrock in Connecticut is of the highly insoluble schist-gneiss type, the majority of the surface waters (75% of those sampled) are very soft (calcium values below 5ppm). Yet, five of the eight *C. chinensis* populations were found in harder waters ( $\text{Ca}^{+2} > 10\text{ppm}$ ) and none lived in waters with  $\text{Ca} < 7\text{ppm}$ . If one statistically compares expected to actual percent occurrence of *C. chinensis* in soft ( $\text{Ca} < 5\text{ppm}$ ) waters (56% expected occurrence, 0% actual) to medium-hard to hard ( $\text{Ca} > 5\text{ppm}$ ) waters (44% expected, 100% actual), using an arcsin transformation (Sokal & Rohlf, 1969), there is a statistically significant difference at the  $t = .02$  level. This indicates that *C. chinensis* is more likely to be found in waters of higher calcium values than

Table 1. Physical/chemical data for the habitats of *Cipangopaludina chinensis* in Connecticut.

Lake or pond	Type	Area		pH	$\text{CO}_2$		Cond.	Color	$\text{Ca}^{++}$		$\text{Mg}^{++}$		$\text{Na}^+$		$\text{K}^+$	
		ha	S		mgC/l				ppm		ppm		ppm		ppm	
Black Pond, Middlefield, Middlesex Co.	NR	30.6	11	7.3	7.6		194	.024	11.4		4.5		8.2		0.5	
Bunnell's Pond, Bridgeport, Fairfield Co.	A	16.6	10	7.1	3.5		207	.025	9.9		3.3		22.0		2.9	
East Twin Lake, Salisbury, Litchfield Co.	N	227.6	15	7.4	33.3		286	.005	35.0		11.6		3.9		2.1	
Goodwin Park Pond, Wethersfield, Hartford Co.	NR	1.8	6	7.0	14.2		280	.222	19.6		4.2		11.9		2.0	
Holbrook Pond, Hebron, Tolland Co.	NR	29.3	8	6.4	4.5		74	.059	7.1		2.0		4.8		0.3	
North Farms Reservoir, Wallingford, New Haven Co.	A	25.3	6	7.5	8.6		158	.041	14.0		3.5		5.5		1.8	
Tyler Pond, Goshen, Litchfield Co.	NR	73.7	6	6.9	7.2		112	.030	7.8		4.1		3.1		0.5	
Lake Wononskopomus, Salisbury, Litchfield Co.	NR	142.7	10	7.5	22.8		217	.010	26.6		8.3		4.5		1.6	

Lake Type: N = natural, NR = natural, water level raised, A = artificial impoundment

S = total number of snail species in lake

lower, and that it may have a physiological need for dissolved calcium levels above 5ppm. Boycott (1936) termed mollusks which could not exist in soft water as "calciphilic". Greater sample sizes and physiological tolerance testing are needed for greater resolution of required environmental calcium values.

### Natural history and Ecology

Data on the life history pattern of *C. chinensis* has been published by Stanczykowska *et al.* (1971, 1972). They estimated the maximum life span for female snails as five years, for males, usually three years, sometimes four. All individuals grew throughout life, with the female's reaching larger sizes because of their longer life span. The females may begin to produce embryos by the end of their first year but the four and five year classes produced the most offspring. Each female produced a minimum of 169 embryos during a life time (an estimation based on embryo counts published by Stanczykowska *et al.*, 1971). Crabb (1929) found up to 102 embryos in one female. The embryos develop in the uterus, and during spring and summer 100% of the females are carrying embryos. The young begin to appear in the population by June and continue to be born through October. The snails begin a migration into deeper water in October, the females appearing to migrate first (Stanczykowska *et al.*, 1971).

Quality of food affects the population parameters of *C. chinensis*. Stanczykowska *et al.* (1972) and Plinski *et al.*, (1978) compared snail populations from three different habitats near Montreal, the Ottawa River, a canal, and a lake. The snails fed on the bottom material which was composed of inorganics, organics and algae. The percent composition of substrate materials was identical to the percent composition of the gut contents, indicating that the snails were not selectively ingesting any specific bottom material. Most of the algae ingested were epiphytic or benthic, indicating that feeding was primarily radular and not by filtration. The ingested algae were primarily diatoms, especially species of *Fragilaria*, followed by greens, blue-greens, and flagellates. The percent composition of algal

forms differed between the three habitats. The Ottawa River snails were larger, heavier, had higher carbon and nitrogen values, and a greater population density than snails from the other two habitats. Sediment and gut analysis revealed that the Ottawa River sediments had not only a higher percentage of algae but a higher diatom content. The lake snails made some attempt to compensate for poorer quality and quantity by consuming greater quantities of substrate. Increase in ingestion rate with a decreased food quality has also been noted for pulmonate snails (Calow, 1975). No studies have been done to date on why diatoms appear to be more nutritious to *C. chinensis* than other algae. The entire area of freshwater gastropod feeding and nutrition is poorly explored.

### Allometric Shell Growth

Shell growth in *C. chinensis* is allometric, that is, the proportions of the shell width to the shell height change throughout development. Consequently, the shell looks different in juvenile and adult individuals. The subject of allometric growth has been explored by Gould (1966 & 1971), White & Gould (1965), and Jokinen (in review). Allometric growth may be analyzed by using linear regression and the resultant curves graphed. Figure 2 illustrates the allometric growth pattern of "typical" *C. chinensis* and compares it to the growth pattern of the *japonicus*-morph. Shell measurements were made to the nearest 0.1 mm with vernier calipers and included embryonic shells. The raw data are available from the author. The data were analyzed using the computer program SAS (Statistical Analysis System) (Barr *et al.*, 1979) and both linear and curvilinear regressions (SAS-General Linear Models and Non-linear Models) were run on shell height vs. width and log shell height vs. log width to determine which model best fit the data. Analysis proved that shell growth in both groups is best described by a linear log shell height vs. log width curve. Log shell height was used as the independent variable.

The ratio of the shell width to the shell height (W/H) decreases as the shell increases in size, the shell becoming relatively more elongate as it



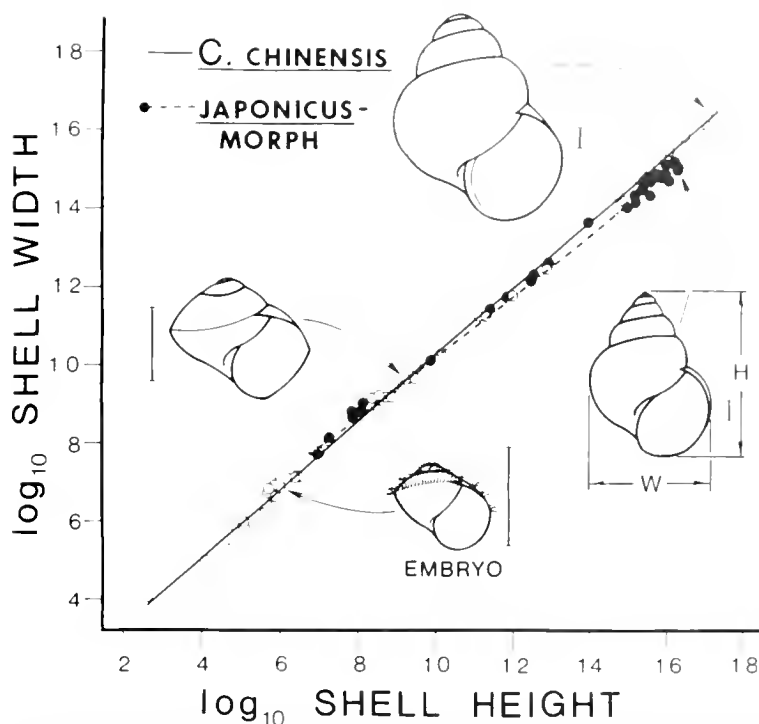


FIG. 2. Allometric shell growth of *C. chinensis* and the *japonicus-morph*. Sketches illustrate the shape of the shells at various points on the curves. The scale bars represent 5 mm. The regression equation *C. chinensis* is  $\log W = 0.84 (\pm 0.004 \text{ S. E.}) \log H + 0.17$ . The regression equation for the *japonicus-morph* is  $\log W = 0.78 (\pm 0.01 \text{ S. E.}) \log H + 0.23$ . The standard error values do not overlap, indicating that the two growth patterns are significantly different. The regression coefficients (slopes) are less than one, meaning that the shell width increases in size at a slower rate than the shell height. The shells, therefore, elongate as they grow. If the slopes equaled unity, both height and width would grow at an equal rate and the shell shape would not change with increase in size.

grows. The regression equation for the relationship between height and width for "typical" *C. chinensis* is  $\log W = 0.84 \log H + 0.17$ ,  $r$ -square = .998. A value of less than unity for the regression coefficient (slope), in this case 0.84, indicates negative allometry, the shell width not increasing as fast as shell height. The regression equation for the *japonicus-morph*, the population from Black Pond, is  $\log W = 0.78 \log H + 0.23$ ,  $r$ -square = .997. The lower slope value, 0.78, indicates that the shell width of the *japonicus-morph* increases even less rapidly than *C. chinensis* shell width. This is reflected in the relatively more elongate shells of the *japonicus-morph*.

Young individuals of *C. chinensis* not only

have a different shaped shell from the older snails but demonstrate marked periostracal spiral hirsuteness. When embryonic shells are placed in water or alcohol and examined under a dissecting microscope, they show a pattern of three spiral rows of stiff periostracal hairs. The hairs are distinctly hooked and the longest hairs are 0.35 mm in length. The hooks face outward from the shell. Some of the larger shells show rows of pits in the same position as the embryonic hairs (see Fig. 2). Since the hairs become obliterated as the snails grow post-partum, their function, if one exists, is most likely intra-uterine. The hairs might serve to hook the embryonic shells together to stabilize their positions in the uterus, or they might function during birth.

### Radular Structure

Radulae of *C. chinensis* individuals were examined for basic structure (Fig. 3). The teeth were separated from each other and mounted in Turtox's CMC-9AF mounting medium which contains acid fuchsin for staining chitinous material. The stain picked-up certain structural details of the central tooth where the radular material is thickened.

*C. chinensis* has the typical taenioglossid tooth number of 7 per row. The central, first and second laterals all have a large central cusp bounded on either side by four smaller cusps. The marginal teeth do not have an enlarged central cusp but have seven small cusps (this number appears to be somewhat variable). Radular structure is similar to that of *Viviparus georgianus* Lea (as illustrated in Clench, 1962) except for the lack of an enlarged central cusp on the marginals of *C. chinensis*. An examination of the radular structure of one individual of the Black Pond population (*japonicus*-morph) revealed five small cusps on either side of the central cusp on the first lateral tooth and nine cusps on the marginal tooth. It is not known if these differences reflect individual variation (if the two morphs are of the same species) or reflect interspecific variation. A much more extensive examination of interpopulation variation is needed before real conclusions can be drawn.

### Parasites

Information is sparse concerning the role of *C. chinensis* as the final or intermediate host of hel-

minth parasites. Penner (1942) found Massachusetts populations to be negative for schistosome parasites. The snail may serve as a final host to the normally clam-inhabiting trematode *Aspidogaster conchicola* von Baer. The snails are infected by eating embryonated eggs passed in the feces of other snails (Michelson, 1970; Huehner & Etges, 1971, 1972, 1977). The snail also serves as intermediate host to a number of echinostome trematodes (U.S. Dept. Agriculture, 1946), including *Echinostoma cinetorchis* Ando & Ozaki, a species which has been reported from humans in Japan, Taiwan and Java (Schmidt & Roberts, 1977). *Angiostrongylus cantonensis* (Chen), a nematode which infects vertebrate nervous systems, may use *C. chinensis* as an intermediate host (Chang *et al.*, 1968). This parasite has been reported from Hawaii and Costa Rica (Schmidt & Roberts, 1977).

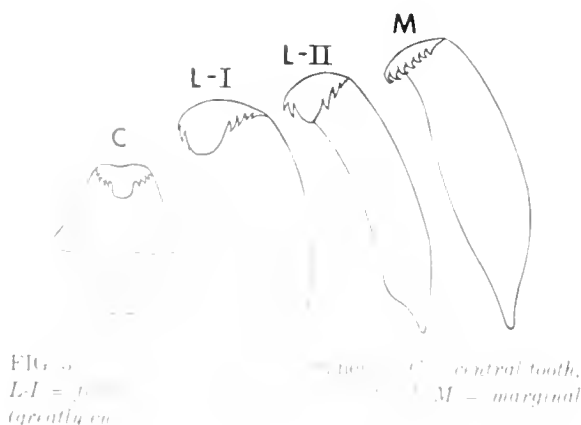
### Summary

The introduced Asian snail, *C. chinensis*, does well in cool-temperate to warm-temperate climates in permanent ponds, lakes and the slow parts of rivers with mud, silt or sand substrates. Available data indicate that the snail requires a minimum of 5ppm calcium in its habitat and is excluded from very soft waters. This species should be considered a well-established part of the North American fauna, especially in the northeastern U.S.

Some basic studies on the natural history and ecology of this species have been undertaken in Canada but more studies should be done to determine what effect populations of *C. chinensis* are having on the native fauna.

More studies need to be undertaken on the parasites carried by *C. chinensis* in North America to determine its potential as a secondary host to both native and introduced Asian parasites.

Shell growth is allometric, the snails tending to become relatively more elongate with age. The embryonic periostracal hairs are stiff and hooked and may serve to stabilize the young snails within the uterus. The shell growth pattern as well as details of the radula structure differ between the "typical" *C. chinensis* and the *japonicus*-morph. Whether or not these should



be considered to be intraspecific individual or interspecific differences awaits more extensive analysis.

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## ERRATA

*Nautilus*, vol. 94 (1) **J. K. Buttner** and **R. C. Heidinger**, "Seasonal Variations – Corbicula – Illinois Fish Pond." Page 9, Table 2, bottom line, for  $10^{-3}$  read  $10^{-4}$ . Page 10, left column near bottom, for  $P > 0.01$ , read  $P < 0.01$ . The authors express their regrets.

## COMMENTS ON THE EASTERN PACIFIC *TRIVIA RITTERI* (GASTROPODA: TRIVIIDAE)

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Although Cate (1979) recently surveyed all known species of Triviidae the information he presented on *Trivia ritteri* Raymond, 1903, was only a condensation of the original description. Not only were no new data presented, but one of the original collecting sites of *T. ritteri* (Cortez Bank, west of San Diego) was omitted. The finding of two specimens of *T. ritteri* from deep water off San Diego, California, occasioned a search for additional information.

### References, Synonymy and Published Records:

*Trivia ritteri* Raymond, 1903: 85-86; Catalina Island (off Monterey); Cortez Bank (54 fms); Catalina Island (off San Pedro) (40 fms); off San Pedro (50 fms); Lowe, 1904: 10; Dall, 1921: 140; Oldroyd, 1927: 10; Cate, 1979: 11, 754; Upper Pliocene, L. 1000 ft (Smith & Emerson, 1955: 99); Anacapa Passage, 34° 00' 38" N, 119° 26' 02" W (27 fms); Anacapa Passage, 34° 00' 38" N, 119° 26' 02" W (29-31.5 fms); 2 1/2

miles N. of W. end of Anacapa Island, 34° 03' 05"-45" N; 119° 26' 02" to 25' 28" W (46-58 fms); Abbott, 1974: 149, fig. 1637

*Pusula ritteri* (Raymond). Burch, 1945: 27-29; 42; off Redondo Beach (25 fms), White's Landing, Catalina Island (40 fms); Pleistocene of Timm's Point, San Pedro. *Decoriatrivia ritteri* (Raymond). Cate, 1979: 11, 98; figs. 94 and 94a.

### Geographic and Bathymetric Distributions:

*Trivia ritteri* has been recorded from the upper Pliocene and the Pleistocene of Los Angeles, and in the Recent from Monterey to San Pedro, Catalina Island, Anacapa Passage and Island, and Cortez Bank. Our knowledge of the distribution of *Trivia ritteri* has been based on just a few specimens.

In the collections of California Academy of Sciences (CAS), Los Angeles County Natural History Museum (LACM), and San Diego Natural History Museum (SDNHM) are numerous

lots of *Trivia ritteri*. An analysis of the accompanying data of those specimens gives a better understanding of the distribution of *T. ritteri* (Table 1). Specimens in the LACM collection extend the range of *T. ritteri* southward more than 400 miles (over 650 km) to midway down the Baja California peninsula (27° N). *Trivia ritteri* is endemic to the California Province (sensu Valentine, 1966), with a few northern records to Monterey (36° N).

*Trivia ritteri* is usually found deeper than 50 m (Figure 1). More than two-thirds of the 113 specimens analyzed for bathymetric occurrence were found between 51–90 meters deep. *Trivia ritteri* has a predominantly insular distribution: the majority of specimens have been collected from the offshore islands of southern California and northern Baja California. Mainland collecting records are either from several miles offshore or from deep trenches (such as La Jolla) which rapidly drop off close to the shoreline.

TABLE 1. Recent records of *Trivia ritteri* with their depth ranges.

Location	Specimens	Depth Range
Central California		
Monterey Bay area	10	60–82 m
Southern California, mainland		
Los Angeles area, offshore (<12 mi.)	7	62–240 m
San Diego, La Jolla trench	2	92–137 m
Southern California, Channel Islands		
San Miguel, Santa Rosa, Santa Cruz and Anacapa Islands	20	33–104 m
San Nicholas, Santa Barbara and Santa Catalina Islands	51	51–102 m
San Clemente Island	6	101–126 m
Baja California, Mexico		
West of Isla Cedros	2	117–146 m
South of Isla Cedros	3	31–37 m
Off Thurloe Head (27° 36' 50" N; 114° 50' 50" W)	1	15–18 m
Off San Pablo Pt. (27° 12' 45" N; 114° 31' 45" W)	1	108–130 m

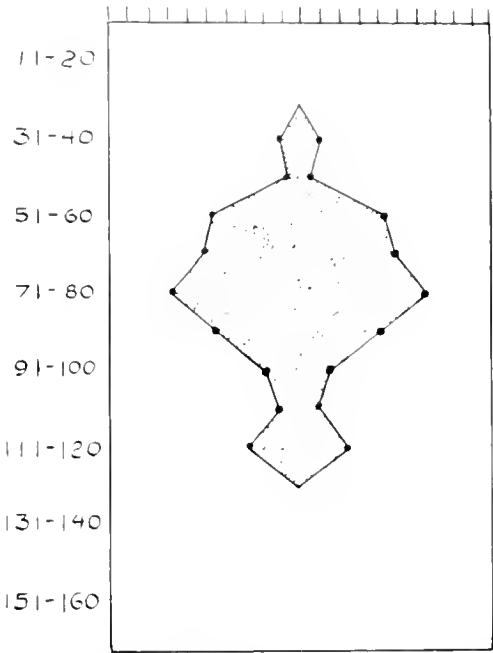


FIG. 1. Bathymetric distribution of *Trivia ritteri*, based on 113 specimens. Vertical numbers are alternating 10 m depths. The mid-point of the collection information was used for specimen lots with a range of depth.

TABLE 2. Shell size and teeth counts of *Trivia ritteri*. Shells in collection of the San Diego Museum of Natural History.

Length and Width	Number of Apertural Denticles	
	Inner Lip	Outer Lip
12 x 9	19	21
12 x 9	17	19
11.5 x 8.5	17	19
11 x 8.5	17	19
11 x 8	16	19
11 x 8	17	19
10 x 7.5	17	19
10 x 7.5	16	18
10 x 7.5	16	18
10 x 7.5	16	18
10 x 7.5	15	17
9.5 x 7	15	17
9.5 x 7	15	18
8.5 x 6.5	17	17
8 x 6.5	17	16
8 x 5	none	none

### Shell Morphology:

Raymond (1903) described the shell characters of *Trivia ritteri* fairly comprehensively; the first published illustration of the species appears to be Abbott, 1974: fig. 1637. Among the material we examined (Table 2) were several immature specimens, a bulloid juvenile form completely lacking apertural denticles and dorsal ribbing (Figs. 2 and 3) and a subadult (Figs. 4 and 5) with teeth, the outer lip still thin but hav-

ing begun folding over the aperture, and the dorsal surface nearly smooth. The animal begins to develop the adult shell morphology (Figs. 6 and 7) when it reaches 6–8 mm. The British *Trivia arctica* reaches the adult stage in 6–8 months (Lebour, 1933).

### Radula:

The radula of *Trivia ritteri* is illustrated here for the first time (Fig. 8). The radula we examined has 22 rows of fully formed teeth, with 2 scythe-shaped marginal teeth and a single large admedian tooth on each side of the median tooth (cf. Schilder, 1936, for terminology). The admedian tooth has a single denticle on the inner side of the erect shaft, and 3 or 4 small denticles on its outer side. The median tooth has a major cusp with 6–8 small accessory denticles on each side.

### ACKNOWLEDGMENTS

We are grateful to those who graciously loaned us specimens or gave us data from collections in their care: Mr. Loyal J. Bibbey; Dr. Barry Roth, California Academy of Sciences; and especially Mr. Gale Sphon and Dr. James H. McLean, Los Angeles County Natural History Museum. We thank Anthony D'Attilio, San Diego Natural History Museum, for the drawings.

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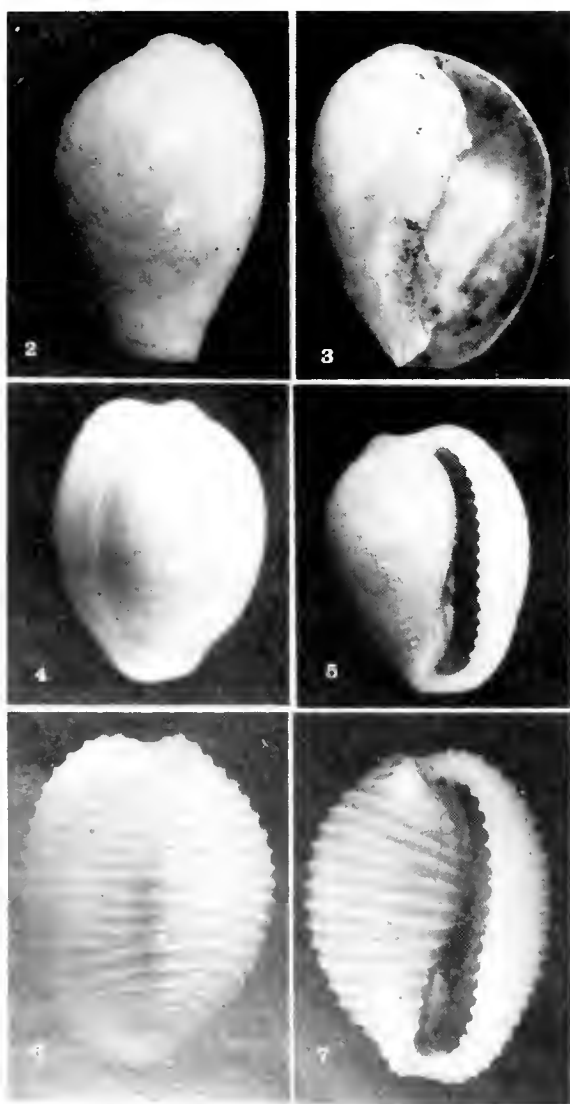


FIG. 7. *Trivia ritteri*, dorsal and ventral views. Photographs by Raymond. 2-3, Juvenile bulloid form; 4-5, Subadult; 6-7, Adult.

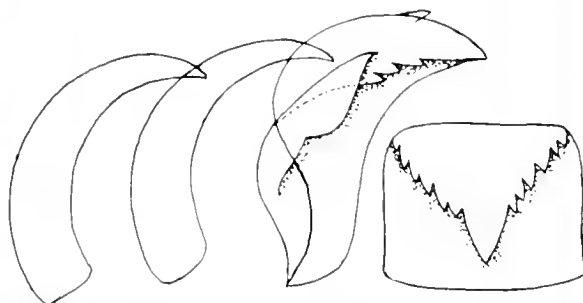


FIG. 8. Radula of *Trivia ritteri*. Drawing by Anthony D'Attilio.

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AN OVERLOOKED *BUSYCON* WHELK (MELONGENIDAE)  
FROM THE EASTERN UNITED STATES

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ABSTRACT

*Busycon laeostomum* new species, a large living sinistral *Busycon* whelk is described from the eastern United States. This new species is compared with *B. carica* (Gmelin, 1791) and *B. contrarium* (Conrad, 1840) and its subgeneric affinities are discussed.

A large, sinistral *Busycon* is occasionally collected offshore along the Atlantic coast of the United States between southern New Jersey and northern Virginia. This whelk frequently has a pure white shell and has been referred to

as either a sinistral form of *B. carica* (Gmelin, 1791) or as *B. contrarium* (Conrad, 1840) (Abbott, 1974, p. 222). Here I show that this whelk is distinct from sympatric *B. carica* and *B. contrarium*, and describe this new species.



FIGS. 1-5. *Nautilus nautilus*. 1, 258 mm (Pope collection); 2, 213 mm (USNM no. 679720); 3, 222 mm (with soft tissues and operculum; Pope collection); 4, 224 mm (USNM no. 806850); and 5, 221 mm (siphonal canal broken; USNM no. 806850).



*Busycon laeostomum*, new species

Figs. 1-5, 7, 10

*Shell Description* – Shell sinistral, solid, subpyriform, inflated; shoulder rounded, tuberculate; spire low, subconical; spiral cords on spire weak or absent; aperture broad, elliptical, longer than siphonal canal; anal ridge on parietal wall narrow, weak; siphonal canal open, somewhat flaring; columella broad, strongly bowed; spiral cords on body whorl restricted to dorsum of siphonal canal, weak; shell exterior usually chalky, white or pale pinkish-orange, occasionally with indistinct slightly darker suffusions; periostracum minutely ciliated; aperture white or light pinkish-orange; apertural lirae absent or rarely weak.

*Description of Animal* – Head and foot black; operculum corneous, elliptical, lingulate, nucleus apical; radula with 3 teeth per row, 5-6 cusps on central teeth.

*Material Examined* – **Holotype** – Length = 245 mm (U.S. National Museum no. 806849); trapped in 10-15 m of water off Stone Harbor, New Jersey, January 1979. **Paratypes** – Length = 184 mm (USNM no. 678850); dredged 8-10 km off Avalon, New Jersey, July 1967. Length = 213, 176 and 138 mm (USNM no. 679720); dredged off Ocean City, Maryland, 1969. Length = 224 and 221 mm (USNM no. 806850) and 222 and 220 mm (M. G. Harasewych collection); trapped off Stone Harbor, New Jersey in 10-15 m of water, January 1979. Length = 220 mm (USNM no. 806851); off Avalon, New Jersey, 1968. Length = 258 mm (Theresa R. Pope collection) and 83 mm (author's collection); collected as beach shells at Tom's Cove, Assateague Island, Virginia, April 1977. Length = 163 mm (Geerat J. Vermeij collection); off Ocean City, Maryland, 1977.

*Type Locality* – Stone Harbor, New Jersey; in 10-15 m of water.

*Range* – Southern New Jersey to northern Virginia; offshore.

*Etymology* – *laeos* (Gk.) = left, *stoma* (Gk.) = mouth.

*Remarks* – *B. laeostomum* is sinistral and has a ciliated periostracum like *B. contrarium*, but otherwise more closely resembles *B. carica* in

general shell shape (Figs. 6-11, Table 1). *B. contrarium* is more slender and has a more angular shoulder than *B. laeostomum*, although tubercles along the shoulder make the latter difference somewhat difficult to observe in photographs (e.g. – Figs. 4 and 10). *B. contrarium* and *B. laeostomum* also differ with respect to the development of these tubercles, the nature of the external spiral cords and apertural lirae, the shape of the columella, and the color of the shell. While *B. laeostomum* has only rounded tubercles along the shoulder, in *B. contrarium* these tubercles are frequently elongated into prominent spines. *B. contrarium* also has well-developed spiral cords and apertural lirae which become obsolete in later whorls. In *B. laeostomum* these cords and lirae are very weakly developed or more commonly completely absent, even in the early whorls (e.g. – compare Figs. 9 and 10). The columella of *B. contrarium* is slender and relatively straight compared to broad, strongly bowed columella of *B. laeostomum*. Finally, the dark brown axial streaks that usually occur on the early whorls of *B. contrarium* (Fig. 9) do not occur in *B. laeostomum*. In *B. laeostomum* 62% of the types (8 of 13) had a pure white shell; the remaining shells were a

TABLE 1. Comparison of northern *Busycon contrarium* and *B. carica* with *B. laeostomum*, with respect to spire angle, the ratio of siphonal canal length to aperture length, aperture shape ( $t$  = aperture width divided by aperture length) and canal shape ( $t$  = canal width halfway along canal divided by canal length). The values listed are means with ranges indicated in parentheses. Shells with badly broken lips or siphonal canals were not measured. Differences were tested for significance with a one-tailed Mann-Whitney U test and the level of significance is indicated by asterisks (i.e., – \* indicates  $p < 0.05$ , \*\* indicates  $p < 0.01$ , and \*\*\* indicates  $p < 0.001$ ).

	<i>contrarium</i>	<i>laeostomum</i>	<i>carica</i>
Spire Angle	94° ** (85-121°)	105° (92-126°)	81° *** (75-90°)
Canal: Aperture Ratio	1.10 *** (0.87-1.48)	0.77 (0.66-0.93)	0.82 (0.72-0.93)
Aperture Shape	0.60 (0.57-0.64)	0.60 (0.57-0.64)	0.58 (0.51-0.63)
Canal Shape	0.19 *** (0.14-0.26)	0.33 (0.24-0.41)	0.29 (0.19-0.35)
N	15	10	12
Size Range	75-224 mm	83-258 mm	93-219 mm

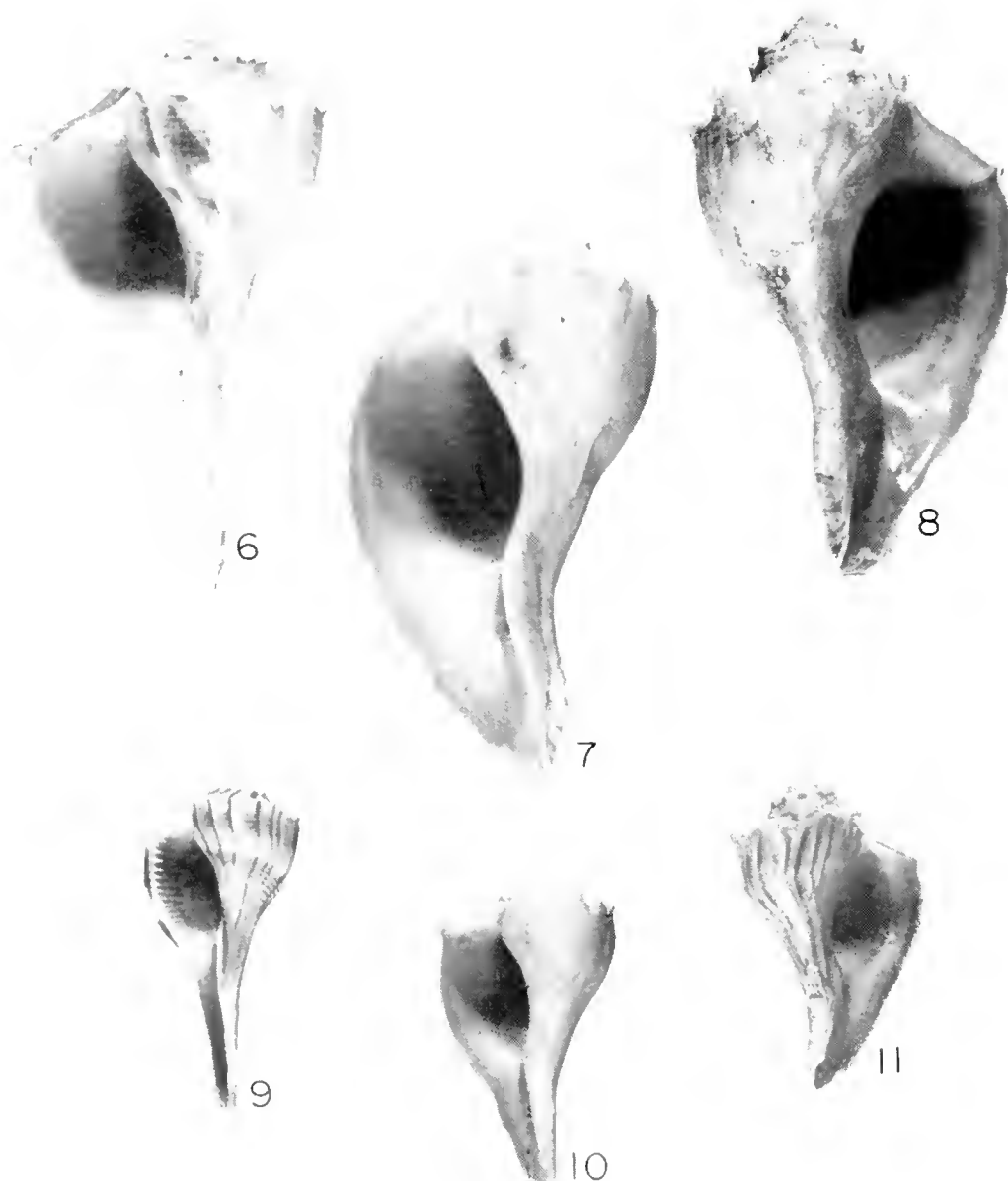


FIGURE 6-11. Comparison of typical adults (upper row) and juveniles (lower row) of *Busycon contrarium* (Fig. 6 and 9), *B. carica* (Fig. 7 and 10) and *B. carica* (Fig. 8 and 11). 6, 224 mm, 7, 245 mm (holotype; USNM no. 806849), 8, 191 mm, 9, 88 mm (Hollister collection), and 11, 93 mm.

1600-1700 orange with slightly darker suffusion. The shell is white (i.e., no axial streaks even in the umbilical region) as are known to occur in

*B. contrarium*, but are very rare (Hollister 1958). I have examined four white *B. contrarium* (USNM nos. 36298, 414722, 609947,

and 631770). Except for the white shells these *B. contrarium* are indistinguishable from other *B. contrarium*. This suggests that *B. laeostomum* is not merely a white-shelled morph of *B. contrarium*. Further, *B. laeostomum* is probably not just a northern form of *B. contrarium*. The two species are sympatric throughout the range of *B. laeostomum*, rather than having contiguous or disjunct ranges as would be expected of geographic morphs.

Although *B. laeostomum* and *B. carica* are similar in shape (Figs. 7, 8, 10 and 11, Table 1), several lines of evidence suggest that they are not merely sinistral and dextral morphs of the same species. *B. laeostomum* and *B. carica* differ, not only with respect to handedness and the nature of the periostracum, but also in spire angle (compare spires in figs. 7, 8, 10 and 11; Table 1), the shape of the anal ridge, and shell color. The anal ridge in *B. carica* is a swollen prominence (Hollister 1958) that is very different from the weak ridge in *B. laeostomum*. *B. carica* also frequently has a bright reddish-orange aperture (Hollister 1958), but this has not been observed in *B. laeostomum*. The white shells which commonly occur in *B. laeostomum* have not been reported in *B. carica*.

If *B. laeostomum* and *B. carica* were sinistral and dextral morphs of the same species they should have similar geographic and bathymetric ranges. The geographic ranges of the two species are very different; *B. carica* occurs from Massachusetts to northern Florida (Abbott 1974), while *B. laeostomum* has a restricted range between southern New Jersey and northern Virginia. The bathymetric ranges are also different. *B. carica* occurs both intertidally and subtidally in areas where it is sympatric with *B. laeostomum* (pers. observ., M. G. Harasewych, pers. comm.), while all of the live-collected *B. laeostomum* were subtidal.

Finally, differences in handedness may preclude copulation between *B. laeostomum* and *B. carica*. There is no direct evidence that sinistral and dextral morphs are unable to copulate, but as Pulley (1959) has argued, even slight difficulty in copulation would reduce gene flow between the two forms. If copulation between the

two morphs were possible, egg capsules should occasionally be found containing both sinistral and dextral individuals. Gill (1867) examined over 500 *B. carica* egg capsules, but found only dextral individuals.

The presence of sinistral coiling and a ciliated periostracum strongly suggests that *B. laeostomum* is much more closely allied to *B. contrarium* than to *B. carica*. Consequently, *B. laeostomum* should be placed in the subgenus *Sinistrofulgur* Hollister 1958 with *B. contrarium* and *B. perversum* Linné 1758.

*B. laeostomum* is also distinct from fossil sinistral *Busycon*, which have either prominent shoulder spines, such as *B. adversarium* Conrad 1862 and *B. obfilosum* (Grabau 1903), or strong external spiral cords, such as *B. obrapum* (Grabau 1903) and *B. perversum roboronense* Gardner 1948. In *B. laeostomum* the shoulder is tuberculate, but not spiny, and the spiral cords are absent or only very weakly developed even in small individuals. The absence of fossil forms similar to *B. laeostomum* suggests that this species is relatively recent, possibly a northern, Pleistocene offshoot of *B. contrarium*.

*Conclusions* – Hollister (1958) reviewed the extant species of *Busycon*, but made no mention of a form resembling *B. laeostomum*. This omission appears to be due to a lack of well-preserved specimens. Except for a few heavily beachworn specimens in the Academy of Natural Sciences in Philadelphia, which may be referable to *B. laeostomum*, no specimens of *B. laeostomum* appear to have been in museums prior to 1967. Beachworn *B. laeostomum* are difficult to separate from *B. contrarium* and *B. carica*, so in the absence of live-collected specimens confusion between the three species was not surprising. Only in the past few years as live-collected *B. laeostomum* became available for study has it been possible to differentiate these three species.

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### NOTES ON THE MORPHOLOGY OF *CANCELLARIA RETICULATA* (GASTROPODA: CANCELLARIIDAE)

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#### ABSTRACT

*Cancellaria reticulata* (Linné, 1767), the type species of the type genus of *Cancellariaceae*, inhabits subtidal sandy bottoms of the temperate and tropical western Atlantic. Externally, the cancellate shell is smooth and well adapted for burrowing. Internally, it has periodic reinforcing structures analogous to muricid varices. With the exception of an enlarged, bilobed left cephalic tentacle, external features, as well as those of the pallial complex and reproductive systems are not unlike those of other Neogastropods. The nervous system differs from the usual rachioglossan arrangement only in the extreme anterior placement of buccal ganglia and the resulting length of cerebro-buccal connectives. The cuticularized lining of the buccal cavity, highly specialized radula, lack of anterior oesophagus, anterior placement of buccal ganglia and simplified alimentary system posterior to the valve of Leiblein are features that distinguish this superfamily from other Neogastropods. Although the food and feeding mechanisms remain unknown, the functional morphology of the alimentary system suggests a diet of soft tissue or fluid. Scanning electron micrographs reveal the complex structure of the radular tip, which raises the possibility that the cancellariid radula was formed by fusion of central and lateral teeth, rather than by the loss of lateral teeth, as previously believed.

The cancellariaceans comprise a small, monophyletic and morphologically compact group of marine neogastropods that inhabit subtidal to bathyal sand and mud bottoms of tropical and temperate regions. The earliest known fossil record is from the Lower Cretaceous (Upper Albian) of Argentina, while the greatest diversity in the Recent is found along the eastern

Pacific coast and in the central Indo-Pacific area. The relationship between numerous cancellariids from various Cretaceous deposits has not been investigated. Several genera based on Cretaceous species have been placed in Cancellariidae by some authors, and elsewhere by others.

The taxonomic position of this group has, until

recently, been uncertain. Troschel (1866) placed the family Cancellariidae in Toxoglossa, based largely on radular characteristics. Thiele (1929) and Wenz (1938-1944) included it in the rachi-glossan superfamily Volutacea. Olsson (1970), also on radular characteristics, erected the order Nematoglossa for the group. Ponder (1973) showed that this lineage diverged from early neogastropod stock with unique modifications of the anterior alimentary system, and erected the superfamily Cancellariacea to include the families Cancellariidae and the extinct Paladmetidae.

Investigations into the anatomy of cancellariids have been limited, concentrating mostly on radular morphology (Troschel, 1865; Barnard, 1958; Olsson, 1970) and on the fore-gut (Graham, 1966; Ponder, 1973).

The following is an account of the morphology of the shell and soft parts of *Cancellaria reticulata* (Linné, 1767), the type species of *Cancellaria*, the type genus of the superfamily. No previous description of its anatomy has appeared, other than several comparative remarks by Graham (1966).

### Materials and Methods

We were fortunate in obtaining a number of preserved specimens from the following localities:

1♀ and 2♂, pumped ashore from approximately 20 meters depth during a beach nourishment project, Atlantic Beach, Duval Co., Florida.

1♀ and 4♂ dredged in 6 meters, W to SW from the southern end of Egmont Key, Florida.

In addition, a number of shells from the following localities were used to investigate shell structure: 4 specimens dredged in 38 meters, S of Sombrero Light, Marathon, Florida. 3 specimens collected on sand, minus tide, Mangue da Olaria, Guarapari, Espirito Santo, Brasil. 2 specimens from St. Lucie Inlet, Martin Co., Florida.

For anatomical studies, preserved specimens were immersed in 10% hydrochloric acid (HCL) until shells were dissolved. Soft parts were then rinsed and returned to 70% ethanol for dissection. Internal shell structure was investigated

by sectioning dry shells on a diamond saw and by fracturing them in a vise.

Radulae and shell ultrastructure were examined on a Novascan 30 Scanning Electron Microscope.

### KEY TO ABBREVIATIONS ON FIGURES

a	- anus
ag	- albumen gland
asg	- accessory salivary gland
au	- auricle
ba	- bulbus aorta
bc	- bursa copulatrix
bg	- buccal ganglion
cbc	- cerebro-buccal connective
cg	- capsule gland
ct	- ctenidium
cut	- cuticularized tube
dasg	- duct accessory salivary gland
dg	- digestive gland
e	- eye
fo	- female opening
gpd	- gonopericardial duct
hg	- hypobranchial gland
ig	- ingesting gland
k	- kidney
ko	- kidney opening
let	- left cephalic tentacle
m	- mouth
me	- mantle edge
moe	- mid-oesophagus
oaoe	- opening of anterior oesophagus
od	- oviduct
opm	- opening of prostrate gland to mantle cavity
os	- osphradium
ot	- oral tube
ov	- ovary
p	- periostracum
pc	- pericardium
pd	- penial duct
pen	- penis
pr	- prostate gland
pro	- propodium
r	- rectum
rnc	- rear of mantle cavity
rs	- radular sac
rt	- radular teeth
s	- siphon
sg	- salivary gland
srn	- subradular membrane
sto	- stomach
sv	- seminal vesicle
td	- testicular duct
te	- testis
vd	- vas deferens
ve	- ventricle
vl	- valve of Leiblein
XLC	- crossed lamellar aragonite collabral
XLT	- crossed lamellar aragonite transverse

### Shell Morphology

**External:** Shell fairly large for genus (to 50 mm), heavy, biconic, and may be pseudo-umbilicate (Fig. 1). Spire sharply conical (spire angle  $56-65^\circ$ ), comprising about  $2/5$  of total shell length. Protoconch paucispiral, of 2 glassy, slightly bulbous, amber-colored whorls, unornamented except by fine pits (Fig. 2). Coiling axis of protoconch deviated from that of teleoconch by  $10-20^\circ$ . Teleoconch, with up to  $7 \frac{2}{3}$  convex whorls, bears prominent collabral and spiral ornament that intersect to produce the cancellate sculpture that gives the superfamily its name. Suture deeply impressed. Spiral sculpture consists of 12-16 major cords on body whorl and 4-6 on penultimate whorl, with 0-2 fine striae between major cords. Collabral sculpture of markedly prosocline ribs varying in number from 12-14 on the first post-nuclear whorl to 28-33 on the sixth post-nuclear whorl. Ribs strong and evenly spaced, except for areas roughly every  $1/3$  whorl where they are weak and more numerous. Aperture large, hemi-elliptical, deflected from coiling axis by  $22-27^\circ$ . Outer lip with shallow indentation posterior to juncture with siphonal canal and 9-13 strong, slightly recessed lirae that diminish rapidly. In-

ner lip with 2 pronounced columellar folds and a distinct siphonal fold. Posterior fold, much the largest, distinctly bifurcate. Anterior fold sometimes subdivided by a shallow furrow, but to a much lesser degree. The posterior fold overlies the siphonal fasciole. Siphonal canal short (about  $1/5$  aperture length), slightly recurved dorsally and to the right. Base color is white, with patches of light ginger to chocolate brown that are sharply limited by both collabral and spiral bands of white. The collabral bands overlie areas of weak ribbing and areas midway between them. Spiral white bands are situated medially and near the siphonal margin. The aperture is white.

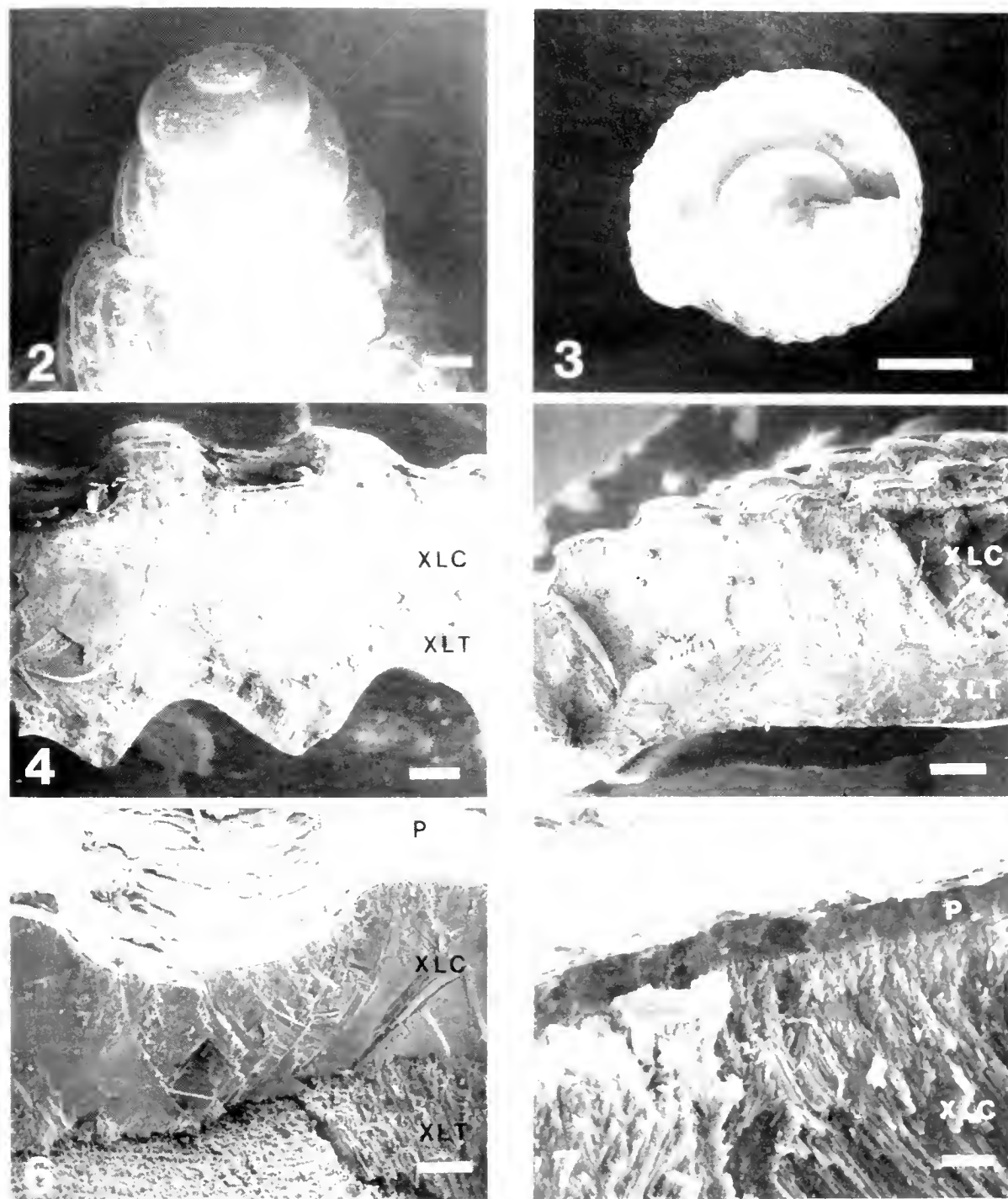
**Internal:** Examination of shells sectioned through planes normal to the coiling axis and transverse to growth lines revealed that apertural lirae and columellar folds are not spirally continuous, but are prominent only every  $1/3$  whorl, and disappear or are greatly reduced between (Fig. 3). The spiral lirae of the outer lip are produced intermittently, and do not extend to the outer lip. The area between the lirae and the edge of the outer lip is thin and corresponds to the areas of weak collabral ribbing noted previously. The columellar folds reach maximum extension into the aperture in direct opposition to maximum liral extension, and are reduced and appressed to the columella between.

**Ultrastructure:** The yellow, unornamented periostracum reaches a thickness of  $4-6 \mu\text{m}$  (Figs. 6, 7 P), and overlies a layer of crossed-lamellar aragonite (Figs. 4-7, XLC) in which the lamellar planes are collabral. As the axial ribs, spiral cords and lirae are composed of this layer, its thickness is quite variable (from 1 to 3 mm in mature specimens). A second crossed-lamellar shell layer (Figs. 4-6, XLT), in which the lamellar planes are roughly perpendicular to those of the preceding layer (XLC) as well as to the coiling axis, lines the inner edge of the shell, and is more uniform in thickness ( $450$  to  $750 \mu\text{m}$ ).

The general form and diversity of sculpturing among 73 living species of Cancellariidae have been illustrated in color in the forthcoming book, the *Compendium of Seashells* (pp. 225-231) by Abbott and Dance (1982). Specimens figured are from the collection of the



FIG. 1. *Cancellaria (Cancellaria) lutea* (Linné). Apertural and right side views. Specimens collected at 6 meters of water, W to SW from the sand bar at Ft. Pierce Inlet Key, Florida. (USNM 806399)



FIGS. 2-7. Details of shell structure of *Cancellaria reticulata* (Linné). 2, Protocoarap. Scale bar = 100 μm. 3, Anterior view of shell in which 1-2 whorl of the outer lip was removed along its midline to show internal structure. Scale bar = 5 mm. 4, Fracture surface. Plane of fracture parallel to outer lip and passing through apertural lobe. Scale bar = 400 μm. 5, Fracture surface. Plane of fracture perpendicular to outer lip. Scale bar = 400 μm. 6, Partial fracture through outer, collibral layer but not through inner, transversal layer. Scale bar = 100 μm. 7, Outer edge of fracture surface in a plane parallel to the outer lip. Scale bar = 4 μm.

junior author and from the type collection at the U.S. National Museum.

### Soft-parts Morphology

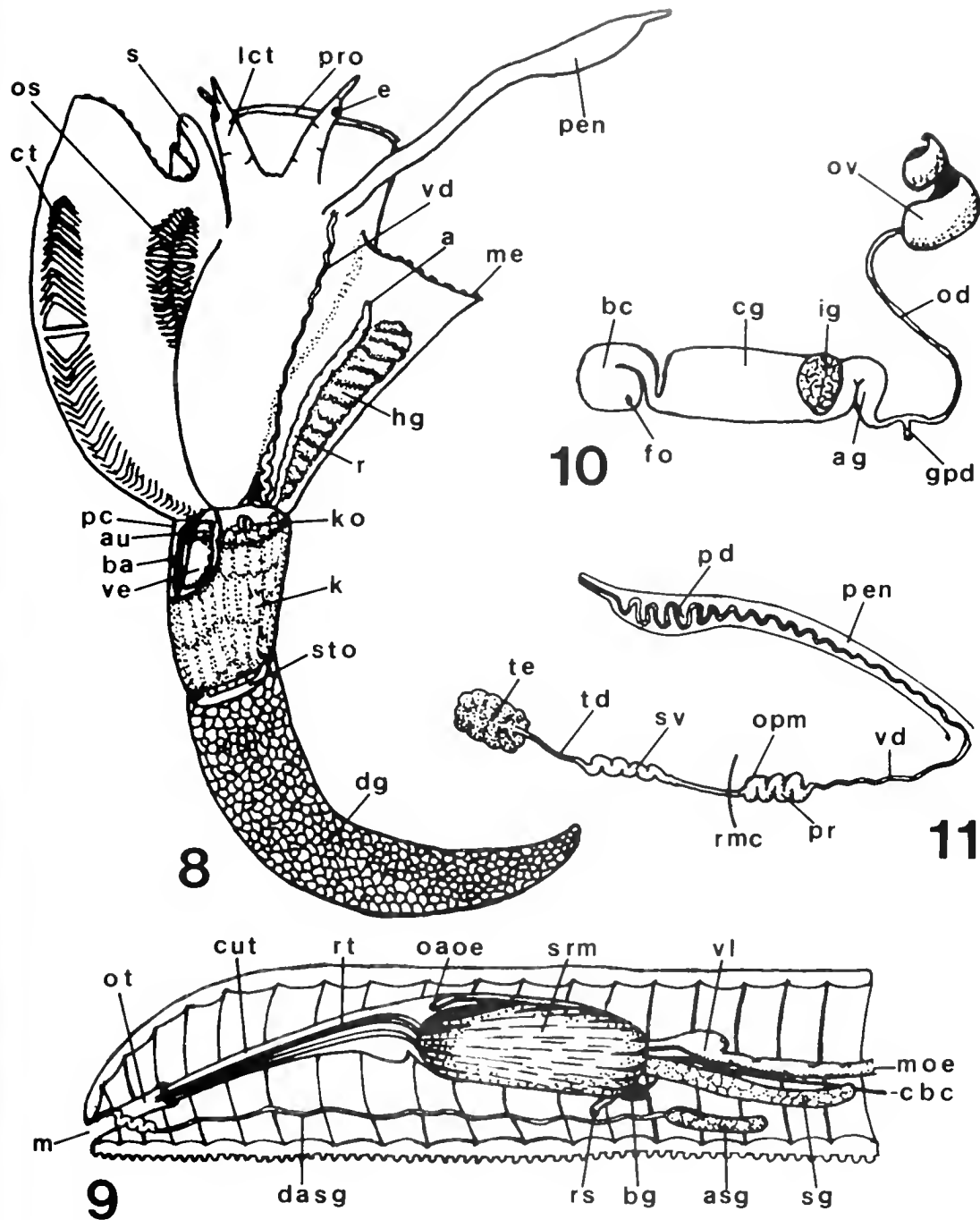
*External features:* The shell-less animal consists of about 5 whorls, of which the mantle cavity occupies approximately 2/3 whorl, the voluminous kidney (Fig. 8, k) 1/3 whorl, and the large digestive gland (Fig. 8, dg) about 4 whorls. Animals were able to retract about 1/2 whorl inside the aperture. The broad attachment area of the columellar muscle is situated below the rear of the mantle cavity when the animal is withdrawn. Preserved animals are uniformly pale orange in color, lacking a discernable pattern. The mantle edge (Fig. 8, me) is thin and finely papillose. The long, narrow, posteriorly tapering foot has a pronounced propodium (Fig. 8, pro) and lacks an operculum. Of the cephalic tentacles, the left (Fig. 8, lct) is longer and broader than the right, and bears 2 papillae above the eye (Fig. 8, e). The siphon (Fig. 8, s) extends slightly beyond the mantle edge and lies over the left tentacle.

*Mantle cavity:* The mantle cavity is narrow and deep, with pallial organs situated as in other Neogastropods. The osphradium (Fig. 8, os) is short (7 mm) and broad ( $L/W = 3$ ), bearing about 70 leaflets per side. There is an unusually large space between the osphradium and the ctenidium (Fig. 8, ct) (about 1.5 times the width of either organ), so that the ctenidium, which is long, slightly narrower than the osphradium and consists of about 250 leaflets, is suspended from the top of the mantle cavity. On the right side of the ctenidium lies the transversely pleated hypobranchial gland (Fig. 8, hg), and to the right of it, the rectum (Fig. 8, r) and genital ducts. The kidney forms the right rear wall of the mantle cavity, and opens into it by a single, vertical slit (Fig. 8, ko). The large pericardium (Fig. 8, pc) is embedded in the left side of the kidney, and forms the left rear wall of the mantle cavity.

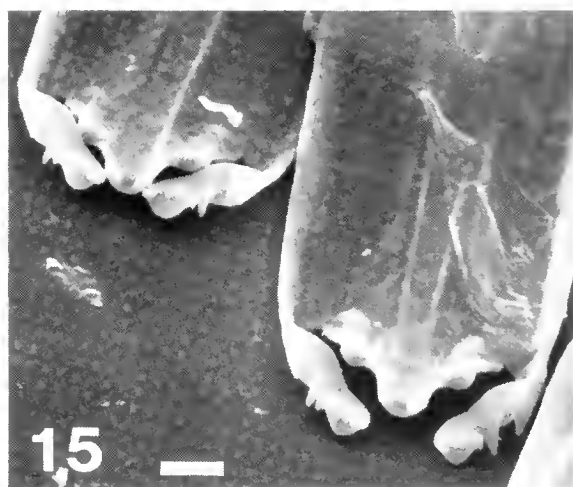
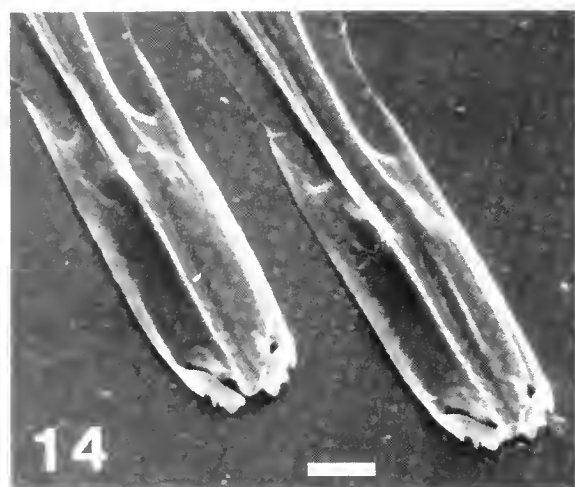
*Alimentary system:* When fully extended, the narrow, pleurombolic proboscis can be protruded through the rhynchostome to a length equal to 1 1/2 times the shell length. It is of the same color as the body, and twice as broad as high, being smooth on the curved dorsal sur-

face and papillose along the entire length of its flat ventral surface (Fig. 9). When retracted, the proboscis is folded within the proboscis sheath. The retractor muscles originate from the body wall as well as from the columellar muscle. From the mouth (Fig. 9, m) situated terminally on the curved anterior of the proboscis, a short (750  $\mu\text{m}$ ) oral tube (Fig. 9, ot) leads to a cuticularized, ventrally overlapping tube-like structure (Fig. 9, cut) [Upper Shield or Mandible of Olsson, 1970], which is narrow anteriorly and expands posteriorly to enclose the buccal mass. The floor of the buccal mass is lined by a broad, cuticularized sub-radular membrane (Fig. 9, srm) [Inner Shield of Olsson, 1970] which supports the radula in a narrow groove. The radula (Fig. 12) consists of a ribbon supporting 73–109 rows of single teeth, of which slightly less than half are directed anteriorly, the balance posteriorly. The anteriorly directed teeth may be protruded slightly beyond the end of the cuticularized tube. The posteriormost teeth are poorly formed, and lie in the radular sac (Fig. 9, rs) which extends slightly below the buccal mass. The division between the anteriorly and posteriorly directed teeth is slightly anterior to the oesophageal opening (Fig. 9, oaoe). Several specimens were observed with groups of teeth (4–9) coiled in a loop under the oesophagus, indicating the mechanism by which they are redirected. Individual teeth are long (1.2–1.9 mm) (Fig. 12), narrow (25  $\mu\text{m}$  at the base) (Fig. 13) and extremely flexible. Toward the tip (Figs. 14, 15), they constrict (20  $\mu\text{m}$ ) and bear 3 highly modified cusps, each with secondary, anteriorly directed cusps. The 2 lateral cusps are directed inward, and interlock medially with the upwardly directed central cusp. The oesophagus opens along the roof of the buccal cavity, where it appears to be cuticularized. At the rear of the buccal mass is the valve of Leiblein (Fig. 9, vl), and beyond it the long, narrow mid-oesophagus (Fig. 9, moe) winds backward to the stomach (Fig. 8, sto). Just behind the buccal mass lie two pairs of salivary glands. One pair (Fig. 9, sg) is narrow and long, entering the buccal mass just anterior to the oesophageal opening. These are homologous to the normal salivary glands of other prosobranchs. The second pair (Fig. 9,





FIGS. 8-11. Anatomical features of *Cancellaria reticulata* (Linné). 8, Male specimen removed from shell, uncoiled and mantle cavity opened mid-dorsally to display contents. 9, Dissection of proboscis tip, viewed from left side. 10, Diagrammatic representation of the female genital ducts. 11, Diagrammatic representation of the male genital ducts.



FIGS. 12-15. Scanning electron micrographs of radula of *Cancellaria reticulata* (Linné). 12, Entire radular ribbon with subradular membrane. Scale bar = 400  $\mu$ m. 13, Attachment of basal ends of teeth to radular ribbon. Scale bar = 10  $\mu$ m. 14, Terminal ends of radular teeth. Scale bar = 10  $\mu$ m. 15, Terminal ends of radular teeth. Scale bar = 4  $\mu$ m.

g) are smaller and sausage-shaped, giving rise to small ducts (Fig. 9, dasg) that lead anteriorly, becoming convoluted and fusing just prior to entering the oral tube near the mouth. These appear to be homologous to the accessory salivary glands of nautilus, nautilus, and volutids. At the ventral end of the buccal mass lie the buccal glands (Fig. 9, bge), and from them the cerebro-buccal nerves (Fig. 9, cbn), bound together with the buccal nerves, run medially down the length of the buccal mass. The oesophagus passes through the buccal mass and concentrated nerve

ring and becomes highly convoluted before entering the stomach. There is no separate gland of Leiblein, but rather a narrow glandular strip runs along the mid-oesophagus. The stomach (Fig. 8, sto), small, narrow and tube-like, runs across the anterior face of the digestive gland (Fig. 8, dg). The narrow oesophagus (1/3 the diameter of the bulbus aortae, Fig. 8, ba) enters on the left, near the opening of the duct to the digestive gland. Longitudinal folds run the length of the stomach into the intestine, which continues as the rectum (Fig. 9, r) along

the right side of the roof of the mantle cavity, but detaches from it 1–2 mm before ending in the anus (Fig. 8, a). There appears to be no anal gland.

**Female reproductive system:** The light-yellow ovary (Fig. 10, ov) lies at the apex of the digestive gland, forming the terminal 1 1/2 whorls. It is composed of numerous thin ascini that converge to form the oviduct (Fig. 10, od) that runs anteriorly along the right ventral side of the visceral mass. The oviduct is joined by the gonopericardial duct (Fig. 10, gpd) just before entering the rear of the mantle cavity and joining the large, arched albumen gland (Fig. 10, ag). Between the albumen gland and the large, rectangular capsule gland (Fig. 10, cg) is the ingesting gland (Fig. 10, ig) that appears as a small mass of dark-brown ridged tubules. Its duct serves as the seminal receptacle. At the anterior end of the capsule gland is the large, squarish bursa copulatrix (Fig. 10, bc). Cutting through the muscular wall reveals an arched, rapidly enlarging tube with the female opening (Fig. 10, fo) at its end. The ventral pedal gland, a 2–3 mm deep invagination lined with glandular folds, is situated along the midline of the sole of the foot, about 1/4 of its length from the anterior edge.

**Male reproductive system:** The dark-brown testis (Fig. 11, te) consists of a mass of ascinous tubules imbedded in the columellar side of the digestive gland. These tubules join together to form a common testicular duct (Fig. 11, td) which runs anteriorly along the right ventral side of the visceral mass. When next to the posterior portion of the kidney, it becomes convoluted, acting as a seminal vesicle (Fig. 11, sv), then straightens and enters the rear of the mantle cavity ventral to the rectum, where it enlarges in diameter and again becomes convoluted. These convolutions act as a prostate gland (Fig. 11, pr), and have an opening to the mantle cavity (Fig. 11, opm). The vas deferens (Figs. 8, 11, vd) winds along the base of the mantle cavity from the prostate gland to the base of the penis (Figs. 8, 11, pen). The penis is long (18–20 mm), narrow (1 1/2–2 mm) and flat, bearing a terminal papilla (2–2 1/2 mm). Judging by the highly coiled penial duct (Fig. 11, pd), the penis is capable of considerable extension.

**Nervous system:** The cerebral, pleural, pedal and suboesophageal ganglia are fused into a concentrated nerve ring through which pass the oesophagus and the anterior aorta. The buccal ganglia are at the base of the buccal mass at the tip of the long proboscis, with the cerebro-buccal connectives reaching 50 mm in length. The supraoesophageal ganglion lies over the oesophagus on the right side of the cephalic hemocoel, just behind the proboscis sheath, and gives rise to the osphradial nerve. The visceral ganglion lies in its usual position at the innermost end of the floor of the mantle cavity.

### Discussion

The anteriorly rounded, posteriorly tapering shell, short siphonal canal, lack of pronounced ornament and smooth surface identify *Cancellaria reticulata* as a frontally burrowing, infaunal neogastropod. The majority of specimens examined (27 of 32) had 1 or more crab breaks on the last whorl. These breaks, however, failed to penetrate beyond the penultimate apertural lirae, suggesting that these serve as shell reinforcements or internal varices. The periodic increase in the size of the columellar folds in opposition to the lirae of the outer lip decreases the size of the aperture and serves, at least in part, an antipredatory function. This periodicity of shell structure indicates that growth is episodic and rapid, occurring in increments of approximately 1/3 whorl.

Knight, et al. (1954) suggested that cancellariids (included in their Volutacea) evolved from the Mesozoic Nerineacea, which, along with some of the Soleniscinae (Subulitacea), had internal folds of considerable complexity. A re-examination of these groups for periodicity of internal structure may shed light on the origins of Cancellariacea.

Ultrastructural studies reveal that the shell consists of a thin periostracum overlying 2 orthogonal layers of crossed-lamellar aragonite. In the outer layer, which comprises the bulk of the shell, the crystal planes are oriented parallel to the outer lip, while in the thinner, inner layer, which lines the inner surface of the shell, the crystal planes are perpendicular to those of the outer layer.

The fracture plane of the thicker outer layer would cause breaks in the shell to run parallel to the outer lip, while the orthogonal inner layer greatly increases the mechanical strength of the shell. In studies of shell crystallography, Böggild (1930) reported that "Different Tertiary and Quaternary species of *Cancellaria* . . . were all quite alike and built up of the ordinary three layers." [transverse, collabral, transverse], but did not indicate where in the shell the sections were taken. Along the inner lip, a layer of transverse crystals is deposited over the outer layer of shell, possibly accounting for the discrepancy.

*Cancellaria reticulata* is similar to other neogastropods in the morphology of its head-foot, pallial complex, reproductive and nervous systems, with the following noteworthy exceptions. The enlarged and bilobed left cephalic tentacle was found, in all the preserved specimens examined ( $n=8$ ), to run along the base of the siphon, with the two papillae extending over and beyond the opening. It is not known if it functions together with the siphon, forming a tube, or is simply oriented in the anteriormost direction. Several other cancellariid species have similar, and, in some cases, more elaborate arrangements (unpublished observations). Of the pallial organs, the position of the ctenidium is unusual, in that it is displayed to the top of the roof of the mantle cavity. The morphology of both male and female reproductive systems is typically neogastropod (as exemplified by *Nucella lapillus*, see Fretter, 1941), with minor modifications only in the anteriormost portion of each system [bursa copulatrix—female; penial papillae—male]. The nervous system differs from that of other neogastropods chiefly in the location of the buccal ganglia and the extreme length of the cerebro-buccal connectives.

The unique and highly specialized alimentary system is the basis for the superfamilial status of the group, yet the food and feeding mechanism remain unknown for all cancellariids. Both Olsson (1966) and Olsson (1970) have speculated that these animals feed on soft-bodied organisms which are "brushed" into the gill chamber with the foot. Like Graham (1966), we found only traces of solid

food in the alimentary systems of the specimens we examined.

The extreme length of the ventrally papillose proboscis suggests that cancellariids feed at a distance on animals or tissues they cannot reach directly. The presence of well developed accessory salivary glands is generally associated with a carnivorous rather than a scavenger diet.

It is currently believed that cancellariid radulae consist of rows of rachidia, the lateral teeth having been lost (Ponder, 1973). Scanning electron micrographs of the distal tips of radular teeth reveal an elaborate cusp structure, which can be interpreted as being a tri-cusped rachidian in which each of the primary cusps have developed secondary cusps. As the lateral cusps bear a strong resemblance to rachiglossate lateral teeth, we feel an alternative interpretation may be that lateral teeth fused with the rachidian prior to elongation in the ancestral cancellariid.

Viewed functionally, the extreme anterior placement of the valve of Leiblein would serve to minimize the volume of food anterior to it, permitting rapid interaction with salivary gland secretions, and, perhaps more importantly, to prevent the backflow of liquified food posterior to it. The lack of a gland of Leiblein, the long, thin oesophagus and simple tubular stomach suggest that little further treatment of food is required prior to digestion.

Based on certain general similarities between the cancellariid alimentary system and those of pyramidellids and melanellids, we suggest that cancellariids are piercing, fluid feeders rather than microphagous grazers.

#### ACKNOWLEDGMENTS

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THE DISTRIBUTION OF *DONAX VARIABILIS* (BIVALVIA) AT SHIP ISLAND, MISSISSIPPI: SOME PALEOMALACOLOGICAL ASPECTS

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*Donax variabilis* is the easily recognized tellinacean bivalve that inhabits the high energy foreshore zone of ocean beaches from Virginia to Texas (Abbott, 1968). This clam is remarkable for its abilities as a rapid burrower, for its tidal migrations on the beachface, and for its occurrence in densely packed "colonies" in an environment from which typically little else is collected alive (Stanley, 1970). The purpose of this note is to describe the distribution of *D. variabilis*, both living populations and dead shells, along a section of moderate energy ocean beach at Ship Island, Mississippi, a barrier island separating Mississippi Sound from the Gulf of Mexico. This section of beach was (in May, 1980) composed of fine quartz sand with a trace of shell fragments, showed no signs of pollution, and featured a foreshore slope of only a few degrees. Other than infrequent churning of the substrate by swimmers using a beach just to the west of the study area, the beachface is undisturbed by man.

Beginning 90 m east of the swimming area on the western end of Ship Island, 11 samples were collected from the middle beachface at 90 m intervals proceeding east along the beach. At each sample station one litre of sand was scooped from the beach and wet sieved using nested screens having openings of 4.0 and 2.4 mm to recover all shells contained in the samples. Live individuals, as well as articulated and disarticulated dead shells, were counted and returned to the beachface. The results of the survey are summarized in Table 1.

Nearly all living *D. variabilis* recovered were about 2 cm in length (adults); only a few individuals were larger or smaller. The majority of the specimens were alive (86%), and the dead shells were mostly disarticulated and abraded (84%). The survey appears to have encountered at least two "regional aggregations" of living *D. variabilis* in the beachface: one at sample stations 3 and 4, and another at stations 7, 8, and 9. All sample stations except 2 and 6 encountered

TABLE 1. *Distribution of Donax variabilis at Ship Island, Mississippi; May 20, 1980.*

SAMPLE STATIONS	Live Clams	Dead Shells	
		articulated	disarticulated
1	51	2	5
2	1	0	0
3	54	0	19
4	42	0	4
5	20	0	2
6	5	3	13
7	93	9	18
8	194	1	3
9	126	1	19
10	19	0	2
11	24	0	1
	N=629	N=16	N=86
	$\bar{x}$ =57.2	$\bar{x}$ =1.5	$\bar{x}$ =7.8
	s=59.0	s=2.7	s=7.8

at least local aggregations. The smaller, local aggregations appeared to be clumped together forming the larger, regional aggregations. Well-defined aggregations were not preserved among the dead shells. The largest local aggregations of living clams occurred near the end of the transect farthest from the public swimming beach.

The distribution of *Donax* is of interest to paleontologists because of its use as an indicator of proximity to ancient shorelines in paleoenvironmental reconstructions (for example, see Mixon and Pilkey, 1976). However, as shown in this study, relatively few dead shells of *D. variabilis* were found *in situ* in the beachface at Ship Island. It seems that after individuals die their shells are temporarily concentrated at the plunge step just offshore from the beachface (see Davis, 1978). Tides and currents probably

redistribute the dead shells to various areas in the nearshore zone and other parts of the inner shelf. This transport of *D. variabilis* shells out onto the adjacent shelf explains the admixture of small numbers of these swash zone inhabitants in Pleistocene fossil assemblages of subtidal marine origin with which we are familiar, and argues against the use of *Donax* as an unequivocal indicator of proximity to ancient shorelines. Moreover, tropical storm overwash and the migration of tidal inlets tend to recycle *Donax* shells into backshore, interdune, and even backbarrier environments. Shells reworked from relict sediments compound the problem (see Pilkey *et al.*, 1969). In conclusion, paleoenvironmental interpretations involving *Donax* always should take into account the taphonomic history and paleosynecologic properties of fossil deposits, and not focus on a few selected taxa as "reliable" indicators of environment.

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# *DIVARILIMA* (BIVALVIA: LIMIDAE) AND A NEW SUBSPECIES FROM THE CARIBBEAN

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## ABSTRACT

*Lima albicoma* Dall, 1886, from the Caribbean Recent, is reassigned to *Divarilima* Powell, 1958, a Recent taxon from the Western Pacific, the ancestor probably being the genus *Badiotella* Bittner, 1890, known only from the middle Trias of Europe. The new subspecies *D. albicoma handini*, is described from the Venezuelan Recent.

*Lima albicola* Dall, 1886, was found off Cuba (type locality) and off Barbados at a depth of about 200 m; it has been re-figured by Abbott (1974:454:5249). This small shell (8 mm) with its long, straight, anterodorsal margin is similar in outline to the large, coarsely sculptured *Lima* s.s., but resembles *Ctenoides* Mörch, 1853, in possessing a divaricate sculpture. It differs from all Western Atlantic limids in having a very deeply excavated lunule, or "truncature", as Dall (1886:225) called it. A similar Recent species from off eastern Australia and Kermadec Island, *Lima sidneyensis* Hedley, 1904, was made the type of *Divarilima* Powell, 1958 (Cox & Hertlein, in Moore 1969:N389), thus drawing attention to the divaricate sculpture, a feature of *Ctenoides*, rather than to the characteristic lunule. *Lima albicola* can be assigned to *Divarilima*. The same lunule is present in another small genus, *Badiotella* Bittner, 1890 (Cox & Hertlein, in Moore 1969:N386), known only from the middle Trias of Europe which, although lacking the divaricate sculpture, can probably be considered ancestral to the present day forms of *Divarilima* from the Western Pacific and Western Atlantic, forms to be regarded as Tethyan relicts.

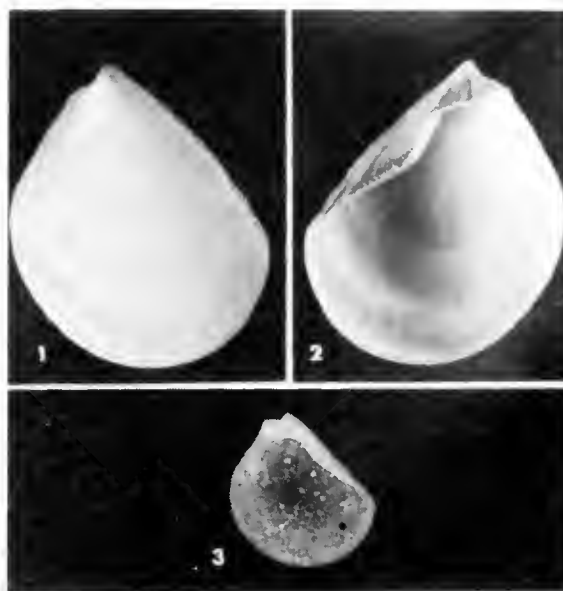
From the north coast of Venezuela comes a second Caribbean form, here named: *Divarilima albicola handini*, n. subsp.

## *Divarilima albicola handini*

Gibson-Smith & Gibson-Smith, n. subsp.

Figures 1, 2.

*Description* – Shell small, trigonally ovate. Anterodorsal margin nearly straight, extended, coinciding with a strong umbonal ridge along which runs a fine keel. Posterior margin almost straight above, these two margins subtending an acute angle at the umbo. Ventral margin deeply rounded. Shell almost equilateral. Poste-



FIGS. 1-3. 1 and 2, *Divarilima albicola handini* n. subsp. Holotype, external and internal views, right valve, height 10.0 mm, length 8.2 mm. Recent of Venezuela. USNM no. 784699. 3, *Divarilima albicola* Dall, 1886. Paratype, internal view, left valve, height 3.8 mm, length 3.3 mm. Caribbean Recent. MCZ 7829.

rior auricle moderate, anterior absent. Cardinal area triangular with a narrow ligament pit overhung slightly by the small sharp umbo; hinge edentulous. Lunule triangular, concave, both borders angulate (90°), sculptured with a weak radial riblet and weaker, irregular, radial wrinkles. Ornament of fine, close, punctate grooves, divaricate along the median line from to umbo to ventral margin; angle of divarication very acute and hardly to be seen. Several strongly marked growth stages stepping down across the disc. Color a very pale brown, translucent; growth stages marked by narrow, opaque white, concentric bands. Remnant of pale brown periostracum within the lunule.

*Holotype* – USNM No. 784699. A right valve, height 10.0 mm, length 8.2 mm, semi-diameter 2.5 mm.

*Type locality* – Recent, Chichiriviche de la Costa, Federal District, Venezuela.

*Remarks* – Apart from the holotype there are two, small paratypes each measuring approximately: height 3.0 mm, length 2.75 mm. All are right valves and came from a sand sample collected at 30 m by SCUBA-diver Alan Handin. A figure of a paratype of *D. albicoma* (courtesy Dr. Kenneth J. Boss, MCZ) is shown for comparison (Fig. 3).

*Comparisons* – *Divarilima albicoma handini*

n. subsp. differs from *D. albicoma* Dall in being less produced anteriorly and posteriorly, resulting in a narrower, more equilateral shell. In *handini* the anterodorsal and posterior margins subtend an acute angle at the umbo; in *albicoma* the angle is obtuse. The narrowness of *handini* is reflected in the much more acute angle of divarication along the median line. Furthermore, *albicoma* is described as having two lines of divarication (the figure even shows three), in *handini* there is only one. Whether the depth ranges of the two forms overlap remains to be seen; it may be significant that neither taxon was found in seafloor samples from nine offshore drilling locations, in water depths from 55 to 150 m.

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## THE SUBFAMILY MELAMPINAE (PULMONATA: BASOMMATOPHORA) IN VENEZUELA, WITH DESCRIPTIONS OF TWO NEW SPECIES

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#### ABSTRACT

*The presence of two, new melampid species in the Venezuelan Recent is reported: Detracia roquesana n. sp. and Tralia venezuelana n. sp., the latter occurring also in the early Miocene Cantaura Formation, Paraguaná Peninsula, and the late Pliocene Mare Formation, Cabo Blanco. T. venezuelana is only the second species of Tralia to be recorded from the Western Atlantic.*

The genus *Melampus* is represented in the Venezuelan Recent by *Melampus*

(*Melampus*) *coffea* (Linnaeus, 1758) (Fig. 1) and *Melampus* (*Pira*) *monilis* (Bruguière, 1789)



(Figs. 2, 3). These two taxa range from Florida and Bermuda to Brazil (Abbott 1974:331). The former is generally known as *coffeus*, but it has been pointed out by Altena (1975:86) that being a noun, it is correctly, *coffeä*. Two other pulmonate genera present in the Recent of Venezuela are *Detracia* Gray in Turton, 1840, and *Tralia* Gray in Turton, 1840. The former is represented in Florida and the northern Caribbean by the type-species *D. bullaeoides* Montagu, 1808), *D. floridana* (Pfeiffer, 1856) and *D. clarki* Morrison, 1951, but in Suriname Altena, 1975:86) and Brazil (Marcus & Marcus, 1965:42) the representative is *D. parana* Morrison, 1951, the type locality being Pará = Belém), Brazil. In Venezuela, *Detracia* has not been found on the mainland but is present on the islands of Los Roques where it is represented by a new species here identified as *Detracia roquesana* n. sp. The genus *Tralia* is known in the Recent of the Western Atlantic by a single species, *T. ovula* (Bruguère, 1789), which ranges from southeast Florida and Bermuda to Barbados (Abbott 1974:33). It has been reported also from the Caribbean coast of Panamá (Olsson & McGinty 1958:19) and from Curacao (Coomans 1958:103), in both instances as *Tralia pusilla* (Gmelin, 1791), a synonym. It occurs also in Venezuela (Figs. 4, 5) where, however, a second, more common form is present which is identified here as, *Tralia venezuelana* n. sp. The ancestor of the latter is present in the early Miocene (Burdigalian) Canaure Formation of the Paraguaná Peninsula; it was referred to, *Tralia* cf. *ovula*, by Gibson-Smith & Gibson-Smith (1979:22), but is now found to be identical with *T. venezuelana* n. sp.; it occurs also in the late Pliocene Mare Formation, Cabo Blanco. The Melampinae are hardly known as fossils in the region, one other record being of *Tralia vetula* Woodring, 1928, from the Pliocene Bowden Formation, Jamaica.

### *Detracia roquesana*

Gibson-Smith & Gibson-Smith, n. sp.

Fig. 6

*Description* – Shell small, about 10 mm in

height, obovate, widest at the middle. Whorls adpressed, about 11 in all, the bodywhorl about two-thirds of the shell height. Protoconch at right angles to shell axis, one-half turn only visible, brown. The shell lacks sculpture and is spirally banded in shades of brown. Aperture narrow, the outer lip not flared. Inner lip with heavy callus, a strong fold at the base of the columella and a weak fold, well within the aperture, at the middle of the parietal area. Above the latter the parietal area is weakly excavated and lacks callus, with the result that the lower edge of the area becomes a broad, low fold, or pseudo-fold. Within the outer lip are 3 to 8 lirae, the lowest and largest projects towards the columella fold, leaving only a narrow gap between. Opposite the parietal fold and pseudo-fold, the gap is again narrowed by two strengthened lirae lying opposite within the outer lip.

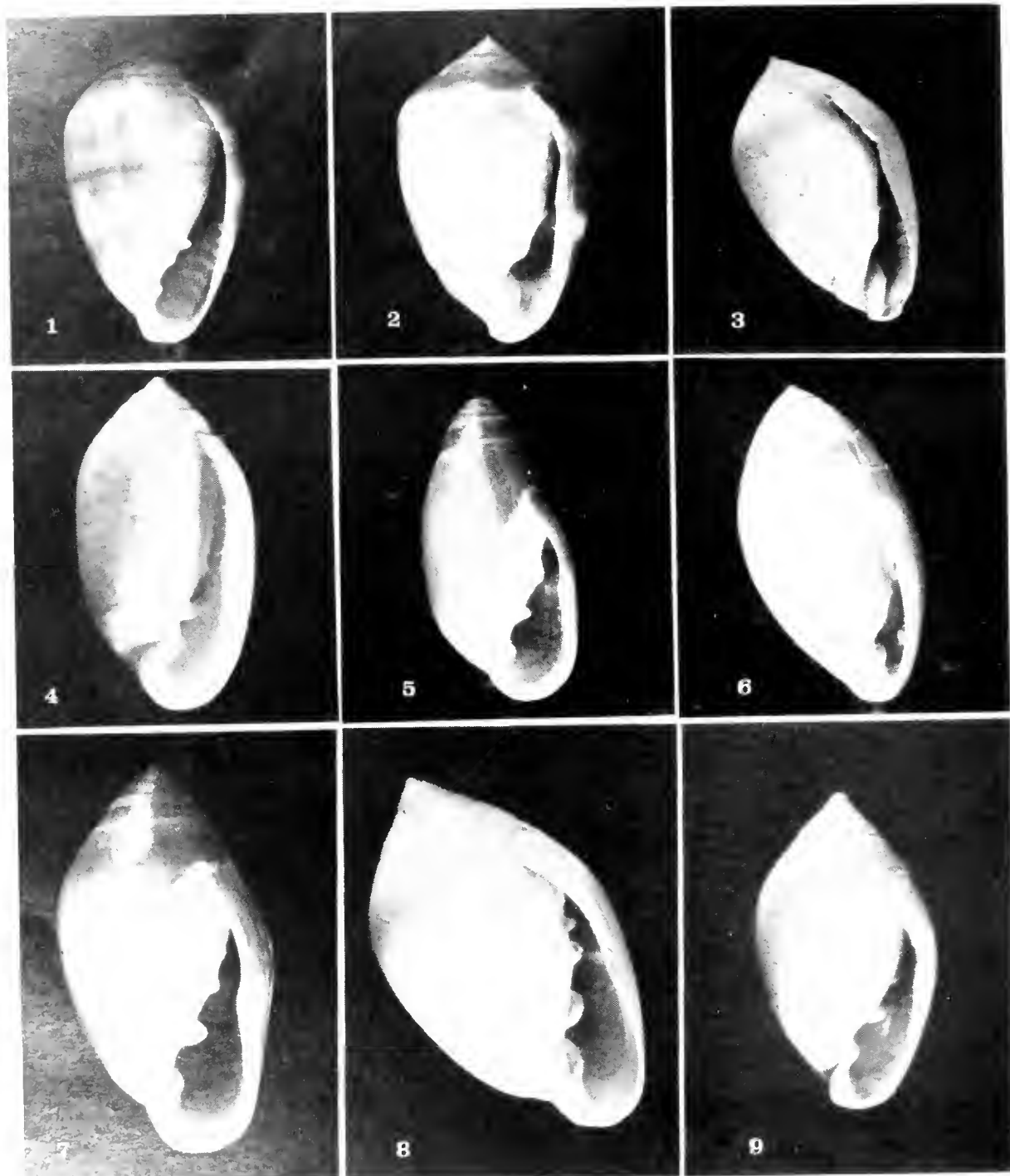
*Holotype* – USNM 784718. Height 10.6 mm, diameter 5.8 mm.

*Locality* – Recent, Islas Los Roques, Venezuela.

*Paratypes* – British Museum (Natural History) and the Natural History Museum Basel. Remainder in the collections of the authors.

*Remarks* – The 6 specimens were collected in beach drift and the exact ecological niche is unknown, but is, presumably, above high tide level as for other members of the family. The islands are fringed by coral reefs and mangroves abound. There is no obvious variation in shell morphology.

*Comparisons* – *Detracia roquesana* n. sp. differs from all the four known Western Atlantic species; *D. bullaeoides* is more elongate, lacks a parietal fold and lirae within the outer lip, and the protoconch is white; *D. floridana* is smaller, more globose and the lirae within the outer lip are not enlarged opposite the columella and parietal folds; *D. clarki* has 2 lower columella folds and is sculptured with spiral, incised lines above the shoulder and around the base and, lastly, *D. parana* is smaller, more rotund and normally possesses only a single, outer lip lira, many shells lacking even that.



FIGS. 1-9. The subfamily Melampinae in Venezuela (for explanations, see opposite).

*Tralia venezuelana*

Gibson-Smith &amp; Gibson-Smith, n. sp.

Figs. 7, 8, 9

*Tralia* cf. *ovula* (Bruguère, 1789), Gibson-Smith & Gibson-Smith, 1979, GEOS No. 24, p. 22.

**Description** – Shell small up to about 15 mm in height, obovate, greatest diameter about the middle. Protoconch small, pimple-like, at right angles to shell axis, about one-half turn only visible. Teleoconch of 8 whorls, the weakly shouldered bodywhorl comprising three-quarters of the shell. Shell glossy, color dark brown with faint spiral and axial banding in shades of brown. Sculpture of up to 9, spiral, pitted grooves above the shoulder, marking the rows of setae of the periostracum; remainder of surface covered with crowded, microscopic scratches, stronger around the base. Shell surface interrupted by growth incrementals. Aperture wider and flaring below, restricted at the middle by a heavy spiral thickening within the outer lip. Columella with a strong basal fold and a stronger one above at the base of the parietal area with, on the parietal area proper, weaker third and fourth folds, the uppermost the weakest, lying well inside the aperture and more easily seen in juvenile specimens.

**Holotype** – USNM 784719. Height 12.7 mm, diameter 7.2 mm.

**Locality** – Recent, Borburata, Falcón State, Venezuela. Living also at other north coast localities from the Paraguaná Peninsula to Carenero, Miranda State, and on the islands of Los Roques, Tortuga and Margarita. As a fossil it occurs in the early Miocene Cantaure Formation, Paraguaná Peninsula, and in the late Pliocene Mare Formation, Cabo Blanco.

**Paratypes** – British Museum (Natural History) and the Natural History Museum Basel. Remainder in the collections of the authors.

**Remarks** – The material available consists of 87 specimens from the various localities; it is from beach drift only, the animal living, presumably, just above high tide level as do other members of the family. There is some variation in globosity. In Venezuela, *Tralia ovula* is largely replaced by *T. venezuelana* n. sp. only 3 specimens of the former having been found, two at Borburata, Carabobo State and one from Islas Los Roques (Figs. 4, 5), two localities where *T. venezuelana* also occurs. From the Cantaure Formation one juvenile (Fig. 9) and one spire have been recovered and from the Mare Formation a spire only with pitted grooves. *T. venezuelana* is only the second Recent species to be reported from the region. Its presence at Cantaure and Mare helps to confirm the shallow water nature of those faunas.

**Comparisons** – The fourth inner lip fold distinguishes *T. venezuelana* from *T. ovula* and from the west coast forms *T. panamensis* (C. B. Adams, 1852) and *T. randerbilti* Schwengel, 1938. *T. ovula*, furthermore, lacks the pitted spiral grooves of *T. venezuelana*. The only other fossil from the region is *T. vetula* Woodring, 1928, from the Pliocene Bowden Formation, Jamaica; it also has pitted spiral grooves at the top of the whorl, but lacks the fourth, inner lip fold and it is smaller and slimmer.

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FIG. 1. *Melampus (Melampus) coffea* (Linnaeus, 1758). Recent, Carenero, Miranda State, Venezuela. Height 9.5 mm, diameter 6.0 mm.

FIGS. 2-3. *Melampus (Pira) monilis* (Bruguère, 1789). Recent, Borburata, Carabobo State, Venezuela. 2, height 12.1 mm, diameter 7.9 mm. 3, whitened, height 8.9 mm, diameter 5.1 mm.

FIGS. 4-5. *Tralia ovula* (Bruguère, 1789). 4, Recent, juvenile, Borburata, Carabobo State, Venezuela, whitened, height 4.6 mm, diameter 2.4 mm. 5, Recent, Islas Los Roques,

Venezuela, height 10.1 mm, diameter 5.0 mm.

FIG. 6. *Detracia roquesana* n. sp., holotype, USNM 784718, height 10.6 mm, diameter 5.8 mm, Recent, Islas Los Roques, Venezuela.

FIGS. 7-9. *Tralia venezuelana* n. sp. 7, holotype, USNM 784719, height 12.7 mm, diameter 7.2 mm, Recent, Borburata, Carabobo State, Venezuela. 8, paratype, whitened, height 7.8 mm, diameter 4.6 mm, *ibid.* 9, Cantaure Formation, Paraguaná Peninsula, Venezuela, height 3.8 mm, diameter 2.2 mm.

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## AN ANCESTRAL *STEPHOPOMA* (MOLLUSCA: GASTROPODA) FROM THE TERTIARY OF VENEZUELA

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### ABSTRACT

*Stephopoma pennatum* Mörch, 1860, from the Panamic Province and not previously known as a fossil, has been found in the early Miocene Cantaure Formation, Venezuela. The only other species in the region is *S. myrakeenae* Olsson & McGinty, 1958, from the Caribbean adjacent to the exit of the Panamá canal. *S. myrakeenae* has not been shown to differ from *S. pennatum* and this raises the question of whether the former is a Miocene relict, or whether the sessile *pennatum* has reached the Caribbean shore via the canal, attached to the hulls of ships.

*Stephopoma pennatum* Mörch, 1860, lives in shallow water in the Eastern Pacific from Nicaragua to Peru. Keen (1971:396:450) places the genus in the Vermiculariinae, probably because of its turretellid operculum edged with bristles. On the other hand, Abbott (1974:101) assigns it to the Vermetidae. The most striking feature is the protoconch which is neither turretellid nor vermetid. It is described by Keen (loc. cit.) as follows: "The initial whorls are flat, resembling a small *Helicæus*, lighter-colored than the adult shell, studded with radial rows of pustules". Olsson & McGinty (1958:35) identified a second species, but from the Caribbean coast of Panamá: *Stephopoma myrakeenae*. They assigned it also to the Vermetidae.

*Stephopoma* Mörch, 1860, the type of which is *Vermetus roseum* Quoy & Gaimard, 1832, from the Recent of New Zealand, is not known as a fossil. However, from the early Miocene (Burdigalian) Cantaure Formation, Paraguaná Peninsula, Venezuela, twelve protoconchs have been collected with great lengths of the disjunctly-coiled shell (Fig. 1). The specimen micrographed here was inadvertently in-

verted when mounted; but no matter. The planorbid protoconch consists of 1 1/4 rapidly expanding whorls, the first half-turn smooth, followed by the pustulose decoration. The irregular adult tube, subquadrate to subcircular in section, is smooth and glossy within; externally, it is closely, longitudinally ribbed, the surface roughened by sinuous growth incrementals, some of which are scaly, and the longest tube measures about 15 mm with a diameter of 2 mm. All this is much as in *S. pennatum*, to which the shell is referred.

The Caribbean *S. myrakeenae* was not differentiated from *S. pennatum* and although it was not described as being ribbed, it was said that most of the adult tubes were very worn. Otherwise, it is indistinguishable and should, perhaps, be added to the short list of species occurring on either side of the Isthmus of Panamá (Radwin 1969:234, 235; Vermeij 1978:213, 269). *S. myrakeenae* was found at Colón and Bocas del Toro Island, some 250 km to the west. The question has to be asked, therefore, whether it is pure coincidence that this Miocene relict found refuge adjacent to the exit of the Panamá canal.

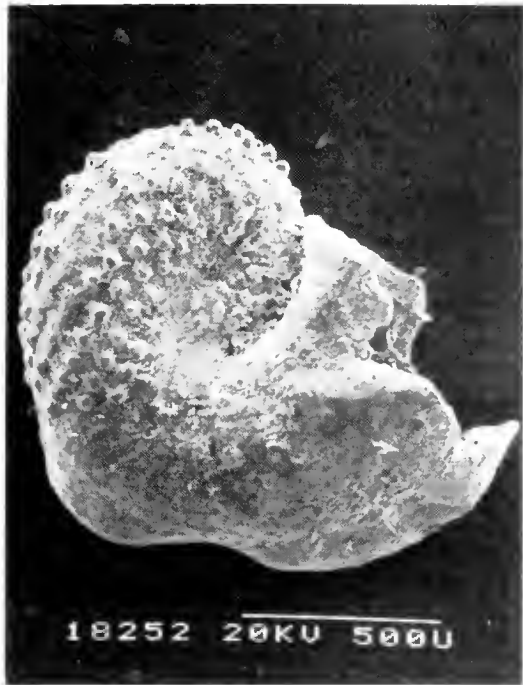


FIG. 1. *Stephepoma pennatum* Morch, 1860. Early Miocene Cantabre Formation, Venezuela. SEM micrograph ( $\times 55$ ). Ventral view of protoconch.

There is the possibility that it is a case of recolonization by *pennatum*, this sessile animal navigating the canal attached to the hulls of ships. The collecting dates were 1917, 1920 and 1953; the canal opening was in 1914, but it is not known whether *myrakeenae* was present at Bocas del Toro Island on the earlier visits. If present only in 1953, just to reach the island would require a migration rate of some 6 km per annum, assisted by the prevailing currents. It might be significant if it were to be found that to the east of Colón, against the prevailing currents, there was a not too distant limit to the occurrence of *myrakeenae*. It has been reported from Payardi Island (Radwin 1969:230), but that lies very close to Colón.

If it is a case of re-colonization, then *Stephepoma* joins the list of "paciphile" genera (Woodring 1966:426). In that case, its extinction in the Caribbean could not have been due to the change in environment induced by the severing of the Atlantic-Pacific connection, an event believed to have resulted in many extinctions

(Woodring loc. cit.). Had it been so, it could not have re-colonized. If extinction occurred, therefore, it was more likely due to the drop in sea-level and temperature during the Pleistocene glaciations (Olsson 1961:7).

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# LARVAL DEVELOPMENT IN *CREPIDULA MACULOSA* (PROSOBRANCHIA: CREPIDULIDAE) FROM FLORIDA<sup>1</sup>

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and

Wesley R. Coe

(posthumous)

Mr. Dale Stingley recently forwarded to *The Nautilus* a letter he found in his files dated October 14, 1952, from Wesley R. Coe, now deceased. The letter contained unpublished information on the type of eggs produced by *Crepidula maculosa* Conrad, 1846. Stingley had sent two or three specimens of *C. maculosa* collected at Sanibel Island in May 1952 to Dr. Coe, who had already published several papers on developmental mode and size of eggs in species of the genus *Crepidula* (Coe, 1949). It was Stingley (1952) who recognized that *C. maculosa* was, indeed, a valid species distinct from *C. fornicata* with which it had been synonymized.

Coe's remarks to Stingley are quoted below. They are significant because of renewed interest in the evolutionary ecology of egg type and larval development in mollusks (Pechenik, 1979; Caswell, 1981). The verification of complete brooding in *Crepidula maculosa* compared with mixed development (brooding followed by planktotrophy) in *C. fornicata*, a larger but similar species, provides another case of divergent modes of egg development in two similar congeners. As found by Gallardo (1977, 1979) for *C. dilatata* and *C. fecunda* in Chile and as discussed by Hoagland (1975, 1977, p. 403) for the genus as a whole, the smaller species of *Crepidula* tend to have direct development of a few yolk eggs while the larger species release numerous planktotrophic veligers that develop from small eggs.

Caswell (1981), uninformed of Gallardo (1979), erroneously stated that individuals of *Crepidula dilatata* could produce one of two types of eggs: those that metamorphose within egg capsules and those that hatch into planktonic larvae. No known species of *Crepidula* can produce both

types of eggs. The works of Stingley and Coe on *C. maculosa* confirm this fact and add to the foundation of systematics and life history required for incorporating *Crepidula* into models of evolutionary ecology.

Remarks on the Eggs of *Crepidula maculosa* by W. R. Coe, 1952 were: "... you may add that a superficial examination of the egg cluster will show a marked distinction from *C. fornicata*. Your collection shows that *C. maculosa* produces at each ovulation about 10 to 12 gelatinous capsules each containing 8 to 10 large ova (0.44 mm in diameter) or about 100 in all. *C. fornicata* on the contrary deposits 40 to 70 capsules each with 120 to 150 small ova (0.17 mm diameter) or 10,000 to 13,000 at one ovulation. The ova of *C. maculosa* (we now know) are completely incubated beneath the parent's foot, while those of *C. fornicata* hatch early into free-swimming veligers."

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<sup>1</sup>The name Calyptraeidae, Fleming, 1824, is also used for Crepidulidae Fleming. The latter name need to be made a *nomen conservandum*—

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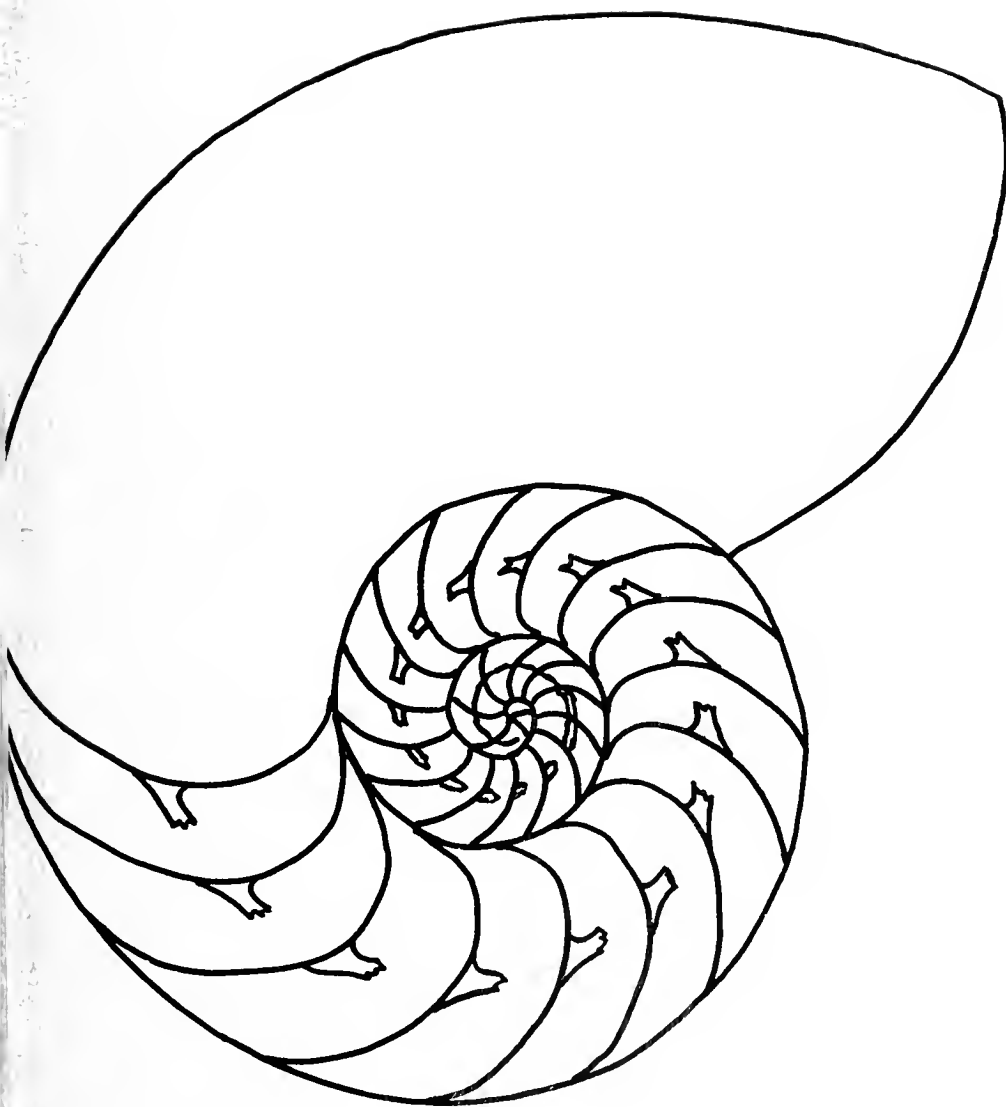
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# A SINISTRAL SPECIMEN OF *SCAPHELLA* FROM THE WACCAMAW FORMATION (EARLY PLEISTOCENE), SOUTH CAROLINA

Jules R. DuBar<sup>1</sup> and Susan S. DuBar

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Morehead State University  
Morehead, Kentucky

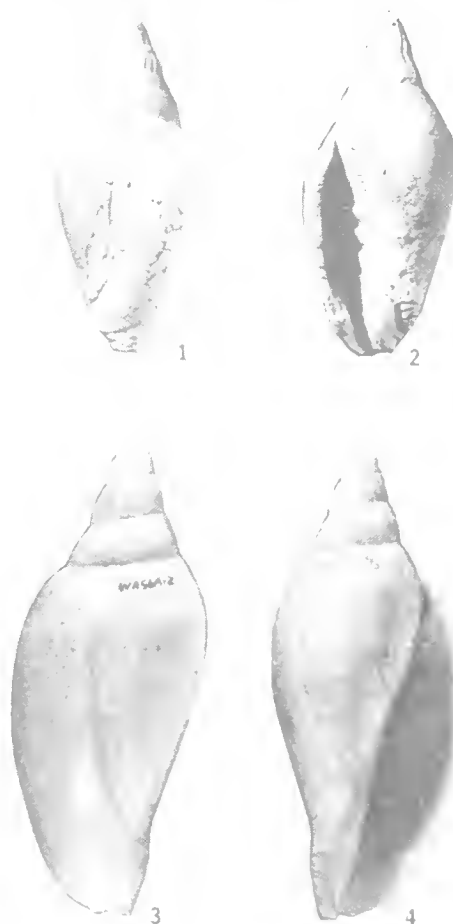
## ABSTRACT

*A sinistral specimen of the volutid gastropod Scaphella floridana brennmortoni Olsson and Petit was collected from the Waccamaw Formation (Early Pleistocene) of northeastern South Carolina. This appears to be the first sinistral specimen of the genus to be recorded from the Neogene of Southeastern United States. The associated shallow water marine faunal assemblage includes numerous semi-tropical and tropical species rare elsewhere in the Waccamaw, or previously known only from late Neogene deposits of southern Florida.*

A sinistral specimen of the gastropod *Scaphella floridana brennmortoni* Olsson and Petit was collected from the Waccamaw Formation (Early Pleistocene) of Horry County, South Carolina (Plate 1, Figures 1, 2). This is the first recorded occurrence of a sinistral specimen of the genus *Scaphella* from the Waccamaw, and to the authors' knowledge, the first recorded from the Neogene (post-Oligocene) of eastern United States. At least three sinistral specimens of the closely related *Scaphella junonia* (Lamarck, 1844) are known from the Recent (Abbott, p. 244, 1974).

The sinistral specimen was found in place in the basal one foot of the Waccamaw where the formation is exposed along the right bank of the Intracoastal Waterway, approximately 14.0 miles northeast of Myrtle Beach, South Carolina (Fig. 1). The enclosing sediment is a slightly indurated admixture of very fine to fine quartz sand (17% by weight), silt and clay (3% by weight), and calcareous shells (80% by weight).

The lower part of the Waccamaw at this locali-



FIGS. 1-4. *Scaphella floridana brennmortoni* Olsson and Petit, 1964, locality WA 56A-2, Waccamaw Formation (Early Pleistocene), Horry County, South Carolina. 1 and 2, sinistral specimen (height restored; 69.2 mm); 3 and 4, dextral specimen (height 91.2 mm).

<sup>1</sup>New address: Bureau of Economic Geology, University Station, Box X, Austin, TX 78712.

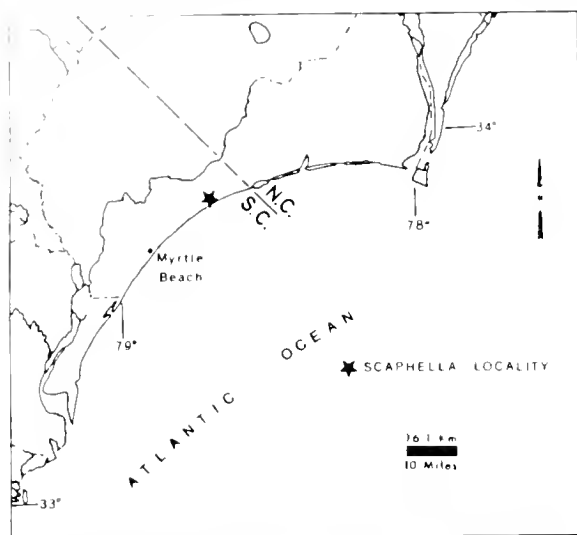


FIG. 1. Map showing locality from which sinistral *Scaphella* specimen was collected.

ty was deposited below wave base, several miles offshore. The sedimentation rate was relatively slow, and turbidity was generally very low. Salinity was normal for the open ocean and bottom water temperatures were in the range of those prevailing today off Southern Florida.

The associated faunal assemblage yielded 30 dextral specimens of *Scaphella* (*Aurinia*) *obtusa* (Emmons) and 49 dextral specimens of *Scaphella floridana brennmortoni* Olsson and Petit (Plate 1, figures 3, 4). In addition, the assemblage included numerous semi-tropical and tropical species rare elsewhere in the Waccamaw or previously known only from late Neogene deposits of southern Florida (Table 1). The total macrofauna exceeds 250 species (DuBar, 1965, 1971).

Generally the morphological features of the sinistral specimen lie well within the observed range of variation for the species. It is noted, however, that the sutural slope angle is slightly greater than that of any associated dextral specimens.

The height of the sinistral specimen is 62.6 mm, however, approximately 7.0 mm of the anterior extremity of the columella has been broken away. The original height of 69.2 mm places it near the median for all associated

specimens (15.5 mm to 138.9 mm) from the same locality.

TABLE 1. Invertebrate species associated with sinistral specimen of *Scaphella floridana brennmortoni* Olsson and Petit.

#### Bivalvia

*Anadara rustica* (Tuomey and Holmes)  
*Anadara scalarina* (Heilprin)  
*Antigona rugatina* (Heilprin)  
*Arca wagneriana* Dall  
*Chama* (*Pseudochama*) *caloosana* Dall  
*Glycymeris americana* (DeFrance)  
*Laccardium laevigatum wagnerianum*  
 Olsson and Harbison  
*Semele leana* (Dall)

#### Gastropoda

*Aesopus stearnsi* (Tyron)  
*Calliostoma wilcoxonianum* Dall  
*Cancellaria renusta* Tuomey and Holmes  
*Diodora caloosensis* (Dall)  
*Diodora carditella* Dall  
*Fasciolaria cronlegensis* Gardner  
*Fusinus caloosensis carolinensis* Dall  
*Murex* (*Chicoreus*) *floridanus* (E. Vokes)  
*Murex* (*Farautia*) *macgintyi* (M. Smith)  
*Murex* (*Phyllonotus*) *globosus* (Emmons)  
*Pterorhytis covardi* Dall  
*Scaphella floridana brennmortoni*  
 Olsson and Petit (dextral specimens)  
*Scaphella* (*Aurinia*) *obtusa* (Emmons)

#### Anthozoa

*Septastraea crassa* (Holmes)

#### Echinoidea

*Arbacia waccamaw* Cooke  
*Glypeaster crassus* Kier  
*Encope michelini imperforata* Kier  
*Rhyncholampus* sp. cf. *R. ayresi* Kier

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## NOTES ON THE FRESHWATER MUSSELS (UNIONIDAE) OF THE UPPER MONONGAHELA RIVER BASIN, WEST VIRGINIA

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### ABSTRACT

*During the spring and summer months of 1980, a preliminary survey of the freshwater mussels of the Upper Monongahela River Basin was conducted. A total of fifteen species of the family Unionidae were found in various tributaries of the Monongahela River, with only the Asiatic clam, Corbicula fluminea being found in the mainstem of the river. Many of the species recorded represent new records for this watershed.*

Information on the extant mussel populations in West Virginia is extremely limited at this time. Recent studies in the state were done by Taylor and Hughart (1981), Morris and Taylor (1978), and Taylor (1980). These studies were conducted on the Elk, Kanawha, and Ohio Rivers, respectively. Bates (1971) attempted a statewide survey, which represents the only recent study performed on the upper Monongahela River Basin. Earlier studies were performed on the Monongahela River by Rhoads (1899) and Ortmann (1909). However, these earlier works were concerned with mussel populations of the Monongahela River and tributaries in Pennsylvania.

### Study Area

The Monongahela River is formed by the confluence of the West Fork and Tygart Valley Rivers at Fairmont in Marion County, in north central West Virginia. The river meanders northward through Marion and Monongalia counties over a course of 60.5 kilometers before exiting the state into Pennsylvania.

Site 1 is located on the West Fork River off county route 25/3 approximately 1.60 kilometers northeast of West Milford in Harrison County. The river originates in southwestern Upshur County and flows in a generally northerly course through Lewis, Harrison, and Marion

counties. The river is 166 kilometers long and falls at an average of 2.13 meters per kilometer.

Site 2 is situated near the mouth of Hackers Creek at U.S. route 19 bridge approximately 3.20 kilometers southeast of Goodhope in the southern portion of Harrison County. Hackers Creek is a tributary of the West Fork River and is 37.19 kilometers long. The stream has a drainage area of 150 square kilometers over its course through Upshur, Lewis, and Harrison counties.

Site 3 is located on Buffalo Creek off county route 1 near Mannington in western Marion County. Buffalo Creek is 48.90 kilometers long and has a drainage area of 323.75 square kilometers. The entire drainage is located within Marion County and falls at an average of 7.30 meters per kilometer. The stream is the largest tributary of the Monongahela River in West Virginia, with the confluence located in North Fairmont.

Site 4 is situated on Dunkard Creek off county route 7/28, approximately 1.70 kilometers northeast of Pentress in northern Monongalia County. The stream is nearly 56.45 kilometers in length as it meanders and crosses the state line six times before it joins the Monongahela River in Pennsylvania. The stream has a total drainage area of 588 square kilometers of which 272 are located in West Virginia.

All stream descriptions are taken from the West Virginia Department of Natural Resources Monongahela River Basin Plan (1981).

### Methods

The specimens used in this study were collected by wading the shallow riffles and pools and hand picking. Empty mussel shells were also collected in this fashion from sand bars and the banks of the streams. The shells collected appeared to have been recently discarded. Each site was visited at least twice during the study period in the spring and summer months of 1980. The Monongahela River was brailed in the fall of 1981 at several locations. No Unionid mussels were obtained nor were there any signs of shells along the river banks. Identification of the specimens collected was aided by the use of Burch (1975) and were verified by Dr. David Stansbery, The Ohio State University.

### Results

A total of fifteen Unionid species were collected during this study (Table 1). The greatest diversity was found in Dunkard Creek (site 4) which supports twelve species. The West Fork River (site 1) and Hackers Creek (site 2) also had

a fairly diverse population. Freshly discarded shells of *Corbicula fluminea* were noted below the locks and dam at Morgantown. This species was also flourishing in the West Fork River.

*Fusconaia flava* represents a new record from the West Fork River, as it was not reported by Bates (1971) and there are no records at the major museums in the eastern United States (pers. comm. Taylor, 1981).

All of the mussels collected on Hackers Creek represent first records, as there are no records of collection on this watershed nor were any of the species reported by Bates (1971). This statement would also apply to the three species collected on Buffalo Creek (site 3).

Many of the species taken from Dunkard Creek are also new records for this watershed in West Virginia. The following species were not reported by Ortmann (1909) nor Bates (1971): *Amblema p. plicata*, *Simpsonaias ambigua*, *Epioblasma triquetra*, *Fusconaia flava*, *Pleurobema sintoria*, *Elliptio dilatata*, and *Tritogonia verrucosa*. Other species collected at this site had been recorded by Ortmann (1909).

It should be noted that two of the species collected appear on the list of Rare and Endangered Mollusks of the United States (USFW, 1971). These species are *Pleurobema clava* from site 2 and *Simpsonaias* (formerly *Simpsoniconcha*) *ambigua* from site 4.

Representatives of the mussels collected in this survey have been accessioned in The Ohio State University Museum of Zoology as voucher specimens.

### ACKNOWLEDGMENTS

I would like to extend my great appreciation to Dr. David Stansbery and Dr. Ralph Taylor for their valuable time and assistance in identification. I would also like to thank the following individuals for their assistance in collecting: Denzil Courtney, Sheila Kelley, Jack Mumaw, Judy Milne Ricketts, and Sheila Zeto.

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TABLE 1. Mussels of the Upper Monongahela River Basin, 1980.

Species	Site No.			
	1	2	3	4
<i>Anodonta g. grandis</i> (Say, 1829)	x	x		
<i>Tropchilus u. undulatus</i> (Say, 1817)	x	x		x
<i>Simpsonaias ambigua</i> (Say, 1825)				x
<i>Tritogonia costata</i> (Pursh, 1829)	x	x	x	x
<i>Tritogonia verrucosa</i> (Ortmann, 1909)				x
<i>Amblema p. plicata</i> (Say, 1817)	x	x		x
<i>Fusconaia flava</i> (Say, 1817)	x			x
<i>Pleurobema clava</i> (Say, 1817)		x		
<i>Pleurobema sintoria</i> (Say, 1817)				x
<i>Elliptio dilatata</i> (Say, 1817)	x	x		x
<i>Tropchilus fuscosignatus</i> (Say, 1817)	x			x
<i>Varia subrotunda</i> (Say, 1817)		x	x	
<i>Elliptio radiata luteola</i> (Say, 1817)	x	x	x	x
<i>Argemone verticosa</i> (Harris, 1833)	x	x		x
<i>Epioblasma triquetra</i> (Say, 1817)	x			x
<i>Corbicula fluminea</i> (Müller, 1774)				x

x = collected at Monongahela River at Morgantown.

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## HELIX ASPERSA AND POLYGYRA CEREOLUS, TWO GASTROPODS INTRODUCED INTO WISCONSIN

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### ABSTRACT

*Two species of land snails, Helix aspersa and Polygyra cereolus, are reported for the first time from Wisconsin. Both species were introduced through the commercial shipment of plants.*

Numerous individuals have reported the spread of both native and exotic mollusks to new localities throughout the United States via commercially shipped plants. Hanna (1966) summarized molluscan introductions into western North America while more recently Dundee (1974) catalogued introduced mollusks of eastern North America. Abbott (1950) gave distributional maps of introduced land and freshwater mollusks, including *Helix aspersa*.

During August, 1980, while examining plants at a local grocery store, the junior author observed a single subadult *Helix aspersa* Müller crawling on the foliage of the creeping fig, *Ficus pumila*. The store manager indicated that all of their plants were purchased from a single supplier located in Wausau, Wisconsin. It was not possible to verify conclusively that the snail had been transported on the fig plant and the owner of the involved nursery firm noted that occa-

sionally snails and slugs were observed on plants shipped from California, Texas, and Florida. *Helix aspersa* is established and/or has been intercepted in the latter two states (Dundee, 1974) and a similar introduction of *H. aspersa* with container grown nursery stock was reported in neighboring Michigan (Hanna, 1969). With the cooperation of the wholesaler, the senior author examined the warehouse for additional specimens. No *H. aspersa* were found. Unlike *H. pomatia* Linnaeus, which at last report (McClary, 1965) was still established near Milwaukee, Wisconsin some 25 years after its introduction (Washburn, 1941), there is no indication that *H. aspersa* has become established as a breeding population within central Wisconsin.

However, several individuals of a second species, *Polygyra cereolus* (Mühlfeld), were collected within the greenhouse. Unlike *H. aspersa*,

the natural distribution of *P. cereolus* is rather restricted geographically. It inhabits the Florida Keys and the rim of the peninsula (Pilsbry, 1940). Although the spread of *P. cereolus* may not be of economic or regulatory concern and no established colonies of *H. aspersa* are known to occur in Wisconsin, they well illustrate the dispersal of mollusks is a continuing problem.

Voucher specimens of both species are deposited in the University of Wisconsin-Stevens Point Museum of Natural History.

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## THE INDIGENOUS DISTRIBUTION OF *ELLIPTIO COMPLANATA* IN OHIO: ARCHAEOLOGICAL EVIDENCE

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#### ABSTRACT

*It generally has been concluded that extra-limital records of the freshwater mussel, Elliptio complanata, in Ohio resulted from species dispersal allowed by the nineteenth century construction of canals. Faunal remains from a prehistoric archaeological site suggest that an earlier mechanism of dispersal was in operation. The potential value of archaeological evidence for zoogeographical studies is stressed.*

The freshwater mussel *Elliptio complanata* (Solander in Lightfoot) is distributed widely in the rivers of the Atlantic Seaboard of North America, in the rivers and lakes of the Great Lakes basin, and in a few rivers flowing into the extreme eastern portion of the Gulf of Mexico. It generally is excluded, however, from the Interior Basin of the Ohio and Mississippi Valleys (Matteson 1948; LaRocque 1967: 171-172).

In Ohio, *Elliptio complanata* has been reported from two localities: Grand River, Ashtabula County (Ortmann 1919: 103) and

Tuscarawas River, Tuscarawas County (Sterki 1907: 393). The Grand River is part of the Great Lakes drainage system; the Tuscarawas River is part of the Ohio River drainage system. The occurrence of the species in the Tuscarawas River, presently unconnected with other rivers from which *Elliptio complanata* is known, requires explanation.

Sterki (1907: 393) suggested that the species migrated to the Tuscarawas River from Lake Erie via the Ohio Canal. While recognizing the possibility of "a very complex and rather un-

likely introduction through drainage changes in the river system." LaRocque (1967: 172) favored the explanation of introduction through nineteenth century canals.

These interpretations of the meager evidence are hampered by limited time depth for distributional data. Molluscan remains from prehistoric archaeological sites, typically collected and identified during the course of archaeological research, can extend that time depth backward considerably.

The Anderson Village site (33-Wa-4) is located in Warren County, Ohio, on the banks of the Little Miami River, a tributary of the Ohio River. During the years around 1350 A.D., it was occupied by Indians of the Fort Ancient Culture. Excavation at the site by Patricia S. Essenpreis in 1976 disclosed a series of refuse pits ("features"), some of which contained several hundred freshwater bivalve shells, apparently the refuse remaining from human meals. These remains subsequently were analyzed and reported by Barber (1978).

The Anderson Village site produced 10 valves of *Elliptio complanata*, 2 from Feature 10 and 8 from Feature 11. Seven of the 10 valves were whole or nearly so and all included both hinge and umbo portions. Preservation of shell was good and the identifications were routine and certain.

These remains of *Elliptio complanata* might be explained in two ways. First, they might be claimed to have been imported from the Great Lakes drainage basin. The distance involved, however, is one of over 100 kilometers and successfully transporting a perishable foodstuff such a distance would have been impossible. The shells were found with domestic refuse indicating simple cooking; there was no evidence

of the use of shells for industrial or other purposes.

Second, the *Elliptio complanata* might have been living in the Little Miami River during the fourteenth century and might have been gathered locally. This explanation is consistent with present knowledge of human resource exploitation and is favored here.

The Anderson Village site remains, therefore, suggest that the Euro-American canals might not have been the mechanism of introduction of *Elliptio complanata* to the Ohio Valley, or at least not the earliest mechanism. Complex river system changes or even fortuitous transportation by mobile animals indeed may have been responsible.

Archaeologists long have sought the advice of zoologists in the interpretation of the faunal remains they encounter. Though largely untapped, archaeological remains form a data base which zoologists profitably could use, especially in zoogeographical studies. Hopefully the future will demonstrate the mutual benefit of increased information exchange between the disciplines.

Identification of the mussel was confirmed by Richard I. Johnson.

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# NEW RECORDS OF CYMATIIDAE (GASTROPODA) IN THE WESTERN ATLANTIC

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Danker L. N. Vink  
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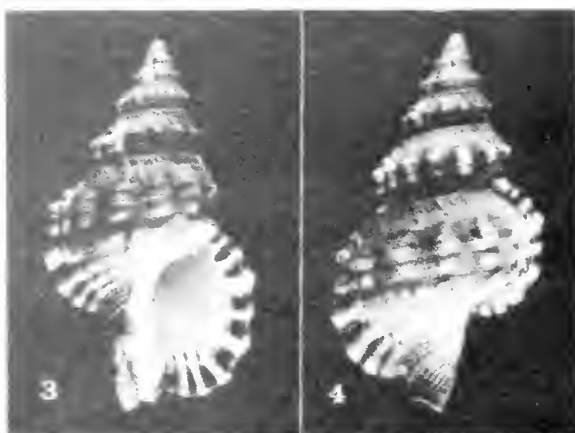
## ABSTRACT

*Since the coverage of the family Cymatiidae for the Western Atlantic by Clench and Turner in 1957, and subsequently by Abbott in 1974, a number of new records in the genera Argobuccinum, Ranella, Charonia, Sassia and Cymatium have turned up in the Caribbean marine province.*

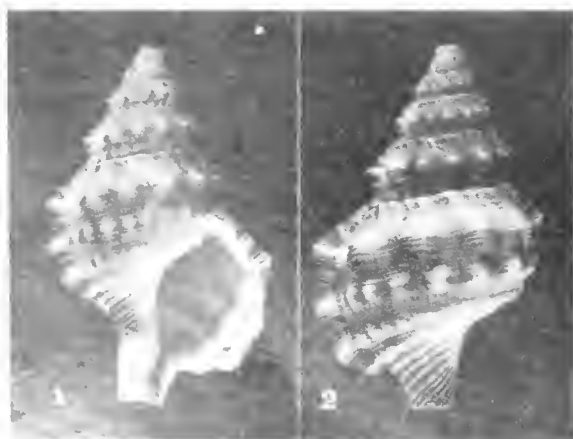
### *Argobuccinum gemmiferum* (Euthyme, 1889)

**Cuba**—An immature worn specimen was taken by José Fernández Milera after a severe winter storm in 1952, washed up on a rocky shoreline, approximately one mile west of the fishing village of Camarioca, Matanzas, not far from Varadero Beach, Cuba.

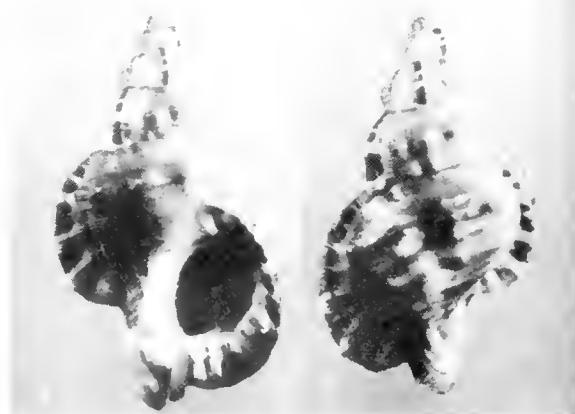
**Brazil**—Dr. Luiz Roberto Tostes kindly sent us an adult specimen taken by a diver alive on sand, near rocks, at a depth of 40-50 metres, near Cabo Frio, Ilha dos Pagagaios, State of Rio de Janeiro. A total of four specimens were taken near Cabo Frio, the largest measuring 126.5 mm in length, and the smallest 101.4 mm. Two of these shells are in the collection of Dr. Tostes, one in the collection of the Museu Oceanográfico de Rio Grande, and the other in the Vink collec-



FIGS. 3 and 4. *Argobuccinum gemmiferum* (Euthyme, 1889). Jeffrey's Bay, South Africa. Length: 123 mm.



FIGS. 1 and 2. *Argobuccinum gemmiferum* (Euthyme, 1889). Camarioca, Matanzas Prov., Cuba. Length: 62 mm.



FIGS. 5 and 6. *Argobuccinum gemmiferum* (Euthyme, 1889). Near Cabo Frio, Ilha dos Pagagaios, R. J., Brazil. Length: 101 mm.

tion. A fifth specimen from Maricá, State of Rio de Janeiro, measuring 110.0 mm, was taken by a fisherman in 70-80 metres, and is also in the collection of Dr. Tostes.

### *Ranella olearium* (Linné, 1758)

*Brazil*—In June 1973, Matthews, Rios and Coelho, described a new Brazilian species of *Bursa* as *B. barcellosi*. The new species was considered by the authors to be closely related to *B. multinodosa* Bucknill, 1927, found in New Zealand waters. Certain differing characteristics however were cited to support the new species, the most important of which was the lack of nodules on the early post nuclear whorls of *B. multinodosa*. From a recent examination of the New Zealand taxon in the collection of the Delaware Museum of Natural History, co-author Finlay has been able to determine that the four examples at the museum revealed nodules on all of the early post nuclear whorls. As only one specimen of *B. multinodosa* was apparently examined, it could be assumed that that specimen was worn and the nodules eroded. Later, Rios, in 1975, considered *B. barcellosi* as a synonym of *Ranella olearium*. Although not so stated by Rios, it would seem that *B. multinodosa* must also appear in the synonymy of *olearium*.

Eight type specimens of *B. barcellosi* (i.e., *Ranella olearium*) were dredged in depths from 100 to 280 metres, by the vessels "Mestre Jeronimo" and "Kosei Maru" from a muddy sand substrate, at stations off Torres, Solidão, Conceição and Albardão, all in the State of Rio Grande do Sul. One of the paratypes was donated to the United States National Museum, Smithsonian Institution, Washington, D.C.

*Bermuda*—In recent years, Jack Lightbourn and Arthur Guest of Bermuda, have taken several specimens of this species in specially devised deep water traps, set in depths of 120 to 140 fathoms (219-256 metres), 1¼ miles off Castle Roads, S. E. Bermuda (all shells were dead, occupied by hermit crabs.) A specimen of the species has been deposited in the collection of the Delaware Museum of Natural History. This species has a worldwide distribution, occurring in the Mediterranean, West Africa, South Africa, Australia and New Zealand.

### *Charonia rubicunda* (Perry, 1811)

*Brazil*—In 1981, Rios and Tostes reported the presence of *Charonia rubicunda* in Brazilian waters. A total of 18 records were cited, from Itajai, State of Santa Catarina, to São Mateus, State of Espírito Santo, between 8 and 50 m in depth. The majority of the specimens, collected in 1976 and 1977, occurred off Cabo Frio, State of Rio de Janeiro. Divers reported that the specimens were taken on a sandy bottom near rocks. This species occurs commonly in Australian waters.

### *Cymatium pharcidum* (Dall, 1889)

*Surinam and Bermuda*—Dall described this species as new in the "Blake Report" from a specimen dredged off Barbados in 82 fathoms (150 metres) on a sandy bottom. Clench and Turner, 1957, considered the species as a synonym of *Cymatium krebsi* Mörch, 1877. Abbott, 1974, suggested that the species might be a "high spired, finely beaded form of *Cymatium respaceum* (Lamarck, 1822) or may be a valid species". It is the considered opinion of the writers that the species is valid. Dr. E. Gittenberger of the Rijksmuseum van Natuurlijke Historie, Leiden, Holland, and D. W. van Veen, presently have a publication in press redescribing and reporting this species from 104 to 130 m off Surinam, some 100 miles north of the Marowijne river. They compared their specimens with the holotype of *C. pharcidum*. The type is illustrated in the forthcoming *Compendium of Seashells* by Abbott and Dance (E. P. Dutton Co., 1982).

Specimens from Bermuda, recently trapped in 120-140 fathoms (219-256 m) 1¼ miles off Castle Roads have been taken by Jack Lightbourn. Specimens from this same source are also in the Delaware Museum of Natural History and Finlay collections.

### *Cymatium trigonum* (Gmelin, 1791)

*Venezuela*—This species had heretofore been known only from the Eastern Atlantic (Cape Verde and Senegal, to Benguela (Angola)). J. W. and F. Gibson-Smith (1970) reported this species washed ashore after a storm in 1967 near

Canaima Grande, Federal District, on the north coast of Venezuela.

***Sassia lewisi* Harasewych and Petuch, 1980**

*Mexico and Barbados*—Specimens of this recently described species, were originally dredged off Contoy Island, Quintana Roo, Mexico, in 60-80 metres, and off St. James, Barbados in 140 metres.

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THE OCCURRENCE AND SPREAD OF THE INTRODUCED  
ASIATIC FRESHWATER CLAM, *CORBICULA FLUMINEA*  
(MÜLLER), IN NORTH AMERICA: 1924-1982

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ABSTRACT

*The distribution and dispersal of Corbicula fluminea (Müller) in North America were examined on the basis of all available published reports of new populations from 1924 through 1982. The dispersal of C. fluminea in North America has proceeded from two epicenters of artificial introduction, the first a result of an introduction from southeast Asia into the northwestern United States, and the second from a population in the Ohio River (probably a result of introduction of specimens from populations earlier established in western United States). The dispersal from these two sites of introduction has been marked by a progressive invasion of adjacent drainage systems, high downstream rates of dispersal and inability to breach barriers to dispersal such as mountain ranges. The very high natural dispersal powers of C. fluminea appear to be associated with its invasive nature and have been previously overlooked as the basis for this species' extraordinarily rapid invasion of North American fresh waters.*

*Corbicula fluminea* (Müller) is a freshwater bivalve in the family Corbiculidae (Newell, 1969) native to southeast Asia (Morton, 1979). This

species was introduced to North America near the end of the 19th century. It was first recorded from the northwest corner of the United

States and has since spread rapidly over many parts of the United States (Cherry, *et al.*, 1980a, 1980b). *C. fluminea* has now been reported in 35 of the continental states, the exceptions being Montana, Wyoming, North Dakota, South Dakota, Nebraska, Kansas, New York, Connecticut, Rhode Island, New Hampshire, Maine, Massachusetts, and Vermont (Cherry, *et al.*, 1980a, 1980b). It has also been reported from fresh waters in northern Mexico (Taylor, 1981; B. Morton, personal communication).

*C. fluminea* has become an important member of many benthic communities in North American fresh waters. Its high growth rates and extraordinary reproductive capacity (Aldridge and McMahon, 1978) allow it to reach very high densities soon after establishment of a new population (McMahon, 1983).

By sheer weight of numbers *C. fluminea* has become one of the most important aquatic pest species in the United States. Its shells accumulate in and obstruct irrigation canals and underground pipes (Eng, 1979; Fitch, 1953; Ingram, 1959; Prokopovich, 1969; Prokopovich and Hebert, 1965). It enters and fouls municipal water treatment facilities (Ingram, 1959; Sinclair, 1974; Smith, *et al.*, 1979). *C. fluminea* also renders dredged river sand and gravel unfit for use as aggregation material in cement (Sinclair and Isom, 1961, 1963). This species has also been reported to outcompete native unionid and sphaeriid bivalves, many of which are presently endangered (Boozer and Mirkes, 1979; Cooper and Johnson, 1980; Fuller and Imlay, 1976; Gardner, *et al.*, 1976; van der Schalie, 1973; Sickel, 1973; Taylor and Hughart, 1981). The most serious aspect of *C. fluminea* as a pest species is its ability to foul the service water systems and steam condensers of electrical generating stations, causing extensive damage to equipment and expensive shut-downs for manual removal of shells (Boozer and Mirkes, 1979; Cherry, *et al.*, 1980a, 1980b; Diaz, 1974; Goss and Cain, 1977; Goss, *et al.*, 1979; Harvey, 1981; Ingram, 1959; McMahon, 1977; Mattice, 1979; Sinclair and Isom, 1961, 1963; Smith, *et al.*, 1979; Thomas and MacKenthum, 1964; Thomerson and Myer, 1970). Perhaps of even greater concern, *C. fluminea* has not only been

reported to foul the steam condensers of nuclear power stations, but, also, to enter and obstruct the emergency reactor cooling systems of these facilities (Parsons, 1980).

While there have been several recently published accounts of the distribution of *C. fluminea* in the United States (Britton and Morton, 1982; Cherry, *et al.*, 1980a, 1980b), there is little published information regarding the actual pattern and pace of the spread of this important pest species in North American fresh waters. Since its probable introduction by Chinese immigrants who may have carried it to North America as a conveniently transported food item (Britton and Morton, 1979; Counts, 1981), it has been presumed by the majority of investigators that the spectacularly rapid spread of this species through North American fresh waters has been the result of human activities including: its use as fish bait (Ingram, 1959); utilization by tropical fish hobbyists as an aquarium specimen (Abbott, 1975); transport of juveniles in the bilge water of pleasure craft or as a tourist curiosity (Britton and Morton, 1979); and, perhaps, unknowingly by fish stocking programs and with transported river sand and gravel used as cement aggregation material (Britton and Morton, 1979; Sinclair and Isom, 1961, 1963).

While human mediated dispersal of *C. fluminea* certainly has occurred, investigators appeared to have generally overlooked this species' great inherent natural powers of dispersal which are associated with its invasive habit and are an apparent adaptation to its preferred disturbed, highly variable, temporally unstable, lotic habitats, from which most unionids and sphaeriids are excluded (Kraemer, 1979; McMahon, 1983). Indeed, the high dispersal powers of the genus, *Corbicula*, are illustrated by the fact that it has a recent fossil history in North America and by fossil record and aminostratigraphic shell dating evidence that indicate that a species of *Corbicula* has reinvaded the fresh waters of southeastern England during each of the last three or four interglacial periods (Miller, *et al.*, 1978).

If the spread of *C. fluminea* in North America was primarily the result of human activity one

would expect that the appearance of new populations would have a largely random component, with upstream invasion rates being equal to or greater than downstream rates, with reports of new populations occurring in habitats great distances outside the previously known species' range and with a marked dispersal of new populations across natural barriers, as mountain ranges, that bisect drainage systems. On the other hand, if the majority of dispersal in this species was by natural means then dispersal would be characterized by a steady, progressive expansion of its range from one closely adjacent drainage system to the next, with no anomalous reports of high upstream invasion rates or the breaching by new populations of natural barriers to dispersal.

In order to better understand the pace, pattern and modes of dispersal of *C. fluminea* in

North America all available literature on this species was surveyed for reports of new populations (primarily in *The Nautilus*) as part of a more extensive review of the biology of this species in North America (McMahon, 1983). The location of each new population and the date on which it was first observed were recorded on an outline map of the United States (Fig. 1). This information was then utilized in the following analysis of the distribution and spread of *C. fluminea* in North American fresh waters.

The first specimens of *C. fluminea* found in North America were recorded as empty shells in Namaino, Vancouver Island, British Columbia in 1924 (Counts, 1981). The first living population was discovered near the mouth of the Columbia River separating Washington and Oregon in 1938 (Burch, 1944) (Fig. 1). From this apparent point of original introduction, *C.*



FIG. 1. Occurrence and spread of *Corbicula fluminea* in North America from 1924 to 1982. Published population records for *C. fluminea* are indicated by the stars and dates on which they were first observed. Probable patterns of dispersal by natural means are indicated by solid arrows while those patterns of dispersal associated with human activity and vectors are indicated by dashed arrows.



*luminea* dispersed throughout North American fresh waters at an extraordinary rate, primarily by successive invasion of adjacent drainage systems (a pattern characteristic of dispersal by natural means).

*C. fluminea* spread southwards in West Coast drainage systems from the Columbia River, reaching the San Joaquin River Drainage System near San Francisco, California, by 1946 (Ingram, 1948). By 1952 it was recorded from drainage systems in extreme southern California (Fitch, 1953) (Fig. 1). During this period of southward expansion on the West Coast no *C. fluminea* populations were reported from east of the Rocky Mountains, which formed an effective barrier to its dispersal (Fig. 1). Only after reaching the southern portions of California, did *C. fluminea* spread to the east, probably through a network of interconnecting irrigation canals into the Colorado River Drainage System where it was first recorded in irrigation canals near Phoenix, Arizona, as early as 1956 (Dundee and Dundee, 1958). From the Colorado Drainage System *Corbicula* spread to the adjacent drainage system of the Rio Grande River, the most likely mode of dispersal again being through irrigation canal systems, where it was first observed in the Rio Grande River near El Paso, Texas, in 1964 (Metcalf, 1966) (Fig. 1). *C. fluminea* quickly extended its range to the downstream portions of the Rio Grande, being reported near the mouth of the river at Brownsville, Texas, in 1969 (Murray, 1971). From the Rio Grande the range of *C. fluminea* expanded rapidly northwards through several closely adjacent Texan river drainage systems reaching northeastern Texas by 1972 (Britton and Murphy, 1977; Aldridge and McMahon, 1978; Pool and McCullough, 1979) (Fig. 1).

While the range of *C. fluminea* was expanding into southern California on the West Coast of the United States, a second, unexpected infestation of this species was recorded in 1957 in the Ohio River, near Paducah, Kentucky (Sinclair and Isom, 1961, 1963). This anomalous population was recorded at a time when the range of *C. fluminea* in the western United States had apparently extended no further east than the Colorado Drainage System in Arizona, 3100 km

southwest of Paducah (Fig. 1). As such, it almost certainly represents an unnatural extension of the range of *C. fluminea* in North America, associated with an, as yet, unidentified human vector. It is highly unlikely that this new infestation was the result of specimens being carried to the Ohio River from western populations by migratory waterfowl as *C. fluminea* cannot survive in their digestive tracts (Dreier, 1977; Thompson and Sparks, 1977).

This artificially introduced population of *C. fluminea* in the Ohio River formed the epicenter of a second major expansion of this species' range in the eastern half of the United States (Fig. 1). From Paducah it spread rapidly downstream in the Mississippi River, reaching the lower portions of the river itself and adjacent Gulf Coastal drainage systems extending into western Florida as early as 1960 (Dundee and Harman, 1963; Schneider, 1967) (Fig. 1). The rapid downstream advance of *C. fluminea* in the Ohio and Mississippi Rivers was almost certainly associated with the ability of its small juvenile stage ( $\sim 0.2$  mm in shell length, Aldridge and McMahon, 1978) to be passively transported by water currents (Goss and Cain, 1977; Goss, *et al.*, 1979; Sickel, 1979; Sinclair, 1964; Sinclair and Isom, 1961, 1963; Smith, *et al.*, 1979). As did the Rocky Mountains on the West Coast, the Appalachian Mountains seemed to have formed an effective barrier to the expansion of *C. fluminea* into the drainage systems of the Atlantic seaboard (Fig. 1). Instead, only after it reached the lower portions of the Mississippi River, did the range of *C. fluminea* expand greatly in an easterly direction, progressing successively across the closely adjacent drainage systems of the lower elevations of the Southern Coastal Plain, extending into extreme southern Florida, by 1969 (Clench, 1970). During this period of range expansion across the Gulf Coastal States, a second anomalous range extension of *C. fluminea* was reported in Lake Overholser, Oklahoma, in 1969 (Clench, 1972) (Fig. 1). Specimens were taken from this lake long before *C. fluminea* had extended into north central Texas and either represent an incredibly rapid upstream expansion in the Arkansas River Drainage System, or, as appears more likely, an artifi-

an introduction by a human vector (Fig. 1).

From the drainage systems of the eastern Gulf Coastal Plain, *C. fluminea* extended into the adjacent fresh waters of the Atlantic Coastal States, being reported from the Atlantic drainage system of Georgia by 1971 (Fuller and Powell, 1973) and reaching as far north as Virginia and New Jersey by 1972 (Diaz, 1974; Fuller and Powell, 1973). Thereafter, the northern expansion of *C. fluminea* slowed greatly with the species still reported to be slowly extending its range in New Jersey (Trama, 1982). The present northern limit of *C. fluminea* in the eastern United States is marked by a marginal population in Lake Erie, Michigan, first recorded in 1980 (Clarke, 1981) (Fig. 1).

*C. fluminea* has now probably reached the extent of its northern distribution in North America. It is apparently excluded from more northern fresh waters by its intolerance of low winter temperatures. Laboratory studies have shown the absolute lower thermal limit of *C. fluminea* to be 2°C (Mattice and Dye, 1976), a minimum temperature exceeded by most bodies of water in the higher latitudes of North America for several months during the winter. Indeed, massive mid-winter mortalities induced by unusually cold ambient water temperatures (< 2°C) have been reported for a *C. fluminea* population in the Ohio River near Cincinnati (Horning and Keup, 1964). In this regard, it is highly significant that populations on the northern edge of the range of *C. fluminea* in the eastern United States appear to be restricted to and to only survive in areas receiving thermal discharges from power stations during winter months (Dreier and Tranquilli, 1981; Eckbald, 1975; Rodgers, *et al.*, 1979; Thomas and MacKenthum, 1964).

The upstream invasion rate of *C. fluminea* appears to be far slower than downstream rates in the major drainage systems in which it has become established (Fig. 1). Of particular interest is the slow upstream expansion of *C. fluminea* in the Ohio River from its point of probable origin near Paducah, Kentucky, around 1957, from which it reached the upstream limit of its range in the Ohio River drainage system in the Kanawha River, West

Virginia, by 1963 (Thomas and MacKenthum, 1964) (Fig. 1). During the same period this species spread downstream a much greater distance into Louisiana, Mississippi and Alabama (Fig. 1). The upstream dispersal of *C. fluminea* in the Mississippi River was similarly slow, with populations reaching Allamakee County, Iowa, in the river proper by 1974 (Eckbald, 1975) and Lake Sangheis, Illinois, by 1973 (Dreier and Tranquilli, 1981) (Fig. 1).

If the majority of dispersal of *C. fluminea* in the United States was mediated by human vectors the upstream dispersal rate should be similar to the downstream rate. Instead, the downstream rate is many times that of the upstream rate in most drainage systems, presumably the result of passive downstream transport of newly released juveniles over relatively large distances on water currents. However, rapid upstream invasion has been recorded for *C. fluminea* in the Tennessee River, where it was found in the river's upper reaches by 1959, only two years after it was recorded at the river's mouth in the Ohio River in 1957 (Sinclair and Isom, 1961, 1963), indicating that human activity may have been implicated in its dispersal in this drainage system.

It appears that much of the dispersal of *C. fluminea* in North America has occurred by natural means. It can be demonstrated that mountain ranges appear to form effective barriers to the extension of the range of *C. fluminea*, and that downstream dispersal rates are generally much more rapid than upstream rates, two factors that would not be characteristic of the more random dispersal patterns that should be associated with human vectors. Upstream dispersal may be the result of transport of specimens in fish digestive tracts as many species are known to feed on smaller (shell length < 5.0 mm) individuals of *C. fluminea* (Britton and Murphy, 1977; Dreier, 1977; Grantham, 1967; Ingram, 1959; Rinne, 1974; Sinclair and Isom, 1961, 1963). A more likely vector for the transport of *C. fluminea* are wading shore birds and waterfowl. Juveniles of *C. fluminea* (< 5.0 mm shell length) have been observed to produce a mucilaginous byssal thread with which they attach themselves to sand grains (Kraemer, 1979) and

particularly to filamentous green algae (McMahon, unpublished observations). Such sand grains and especially filamentous green algae could easily become attached to or entangled in the feet of wading birds or ducks (many species of which feed on *C. fluminea*, Dreier, 1977; Thompson and Sparks, 1977, 1978) and be subsequently transported into upstream habitats. Obviously, it is also highly likely that such transport by bird vectors may be the major mode of dispersal between closely adjacent drainage systems and could, therefore, along with passive dispersal of juveniles by water currents, account for most of the rapid range expansion of this species in North American freshwaters. In contrast, longer-term migratory flights would expose juveniles to lethal levels of desiccation and would, therefore, prevent transportation across mountain ranges.

Consequently, it appears that while there have been several obvious instances of human mediated introductions of *C. fluminea* into North American freshwater habitats, the majority of the dispersal of this species appears to have been by natural means from perhaps two major epicenters of artificial introduction, one in the Northwest corner of the United States and a second in the Ohio River. The dispersal of *C. fluminea* from these two sites of introduction has been marked by a steady progression of its range through adjacent drainage systems, higher downstream than upstream invasion rates and the obstruction of its dispersal by mountain ranges, a pattern of range expansion generally associated with natural modes of dispersal.

Of apparent high importance in the rapid expansion of the range of *C. fluminea* in North America is the passive transport of its juvenile stage over large distances on water currents. In this regard, human activities in the navigable waterways of the United States as dredging and canalization not only appear to jeopardize native unionid and sphaeriid species (Kraemer, 1979; McMahon, 1983) but, also, to optimize conditions for passive dispersal of *C. fluminea* on water currents.

Certainly, the extraordinary rate at which *C. fluminea* has spread through North American

fresh waters (Fig. 1) no longer requires explanations based solely on human vectors. Rather, it may have occurred primarily by natural means that are clearly associated with the highly invasive nature of this species and with the remarkable capacities for dispersal, as evidenced in the fossil record (Miller, *et al.*, 1979), of freshwater members of the genus, *Corbicula*, as a whole.

#### ACKNOWLEDGMENTS

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## HERMAPHRODITISM, SEXUALITY AND SEX RATIO IN THE SURF CLAM, *SPISULA SOLIDISSIMA*, AND THE SOFT-SHELL CLAM, *MYA ARENARIA*

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### ABSTRACT

*In the surf clam, Spisula solidissima and soft-shell clam, Mya arenaria, hermaphroditism is an anomalous condition of very low prevalence (ca. 0.13% for surf clams and 0.35% for soft-shell clams). No conclusive evidence was found that environmental stress caused the condition or influenced the sex ratio, which was approximately equal for both species.*

Accidental functional hermaphroditism in the dioecious surf clam, *Spisula solidissima* Dillwyn, was reported by Ropes (1968a) from a

single individual taken from off False Cape, North Carolina. He pointed out that this anomaly is rare, in part because the gonadal tissues

must be prepared histologically and examined microscopically to detect the condition, but more importantly because the condition is an unusual deviation from normal gametogenesis in pelecypods (Pelseneer, 1894; Coe, 1943, 1944; Galtsoff, 1961). Its rarity suggests that two additional specimens found recently be documented.

The discovery of accidental functional hermaphrodites in species thought to be normally of separate sexes (unisexual, dioecious, or gonochoristic) has resulted in speculation about its cause. A discussion of the condition in surf clams and soft-shell clams (*Mya arenaria*) is included relating possible causes to sexuality and the sex ratio of the two species.

### Methods

The preparation of gonadal tissues for microscopic examination was by standard histological methods outlined in Ropes and Stickney (1965).

### Results

The first hermaphrodite was among 14 dredge samples and 132 clams collected from off Point Pleasant, New Jersey, during January to November 1968 (Fig. 1 A-B). It was found with four females and five males sampled on August 7 from a 68 ft (ca. 20.7 m) depth about 10 n mi (ca. 18.5 km) east-southeast of the Manasquan Inlet entrance (40°00'N Lat., 73°53'W Long.).

The second hermaphrodite was among nine dredge samples and 87 clams collected during a June 20 to July 2, 1969 assessment survey (Fig. 1 C-F). It was found with nine females and one male sampled on June 22 at a 76 ft (ca. 23.2 m) depth about 24 n mi (ca. 44.5 km) east of Little Egg Inlet (39°35'N Lat., 73°47'W Long.).

Both specimens were bilateral hermaphrodites, as was the earlier example, and gametogenesis in testicular and ovarian alveoli was much like that described for the earlier specimen (Ropes, 1968a). A major difference in the clams reported herein is that the gonads also contained a trematode parasite of uncertain identity (Yancey and Welch, 1968). The parasite effectively castrate infected clams by invading the ovarian alveoli. In the hermaphrodites the parasite was found in the ovary, while in the non-

mal gametogenesis comprised about 20% of the gonad; the parasites filled the lumina of remaining alveoli.

### DISCUSSION

Hermaphroditism may be a positive evolutionary response by some bivalve species, permitting survival under unfavorable environmental stress, such as low salinity or fresh water conditions (Fretter and Graham, 1964). Purchon (1968) postulated that a delicate balance exists for the expression of the gonochoristic or hermaphroditic state in mollusks, and considered the former a more primitive condition. Further, he felt that young mollusks have a latent capacity to develop in either state; the transition possibly effected by genetic or environmental changes.

Direct causality between specific intrinsic or extrinsic factors and the expression of hermaphroditism has not been found. Castration from parasites invading the gonad may upset the balance between male and female potentialities, but the mechanism is not understood (Noble and Noble, 1961). Malek and Cheng (1974) noted that the evidence for true sex reversal in mollusks suffering from parasitic castration was inconclusive, because the gonidia for one sex may not be completely destroyed by parasitic infection. This was the case in the two infected hermaphroditic surf clams from New Jersey; cells denoting male and female sex were observed in development (Figure 1). The parasite was found in other surf clams that showed no apparent signs of bisexuality.

Environmental stress has recently been cited as the possible cause of accidental functional bisexuality in the soft-shell clam, *Mya arenaria* (Otto, 1973). Ten hermaphroditic clams were found in 1,311 examined from low salinity (3.0-13.8‰) areas of Chesapeake Bay, a prevalence rate of 0.76% (Otto, 1973). The Chesapeake clams which are near the southern limit of their geographic range (Hanks, 1963), were seriously affected by dilution of the Bay water after a 1972 hurricane (Shaw and Hamons, 1974). The hermaphroditic soft-shell clams studied by Otto (1973) ranged from 50 to 70 mm in shell length and were considered



FIG. 1. Sections of the gonads of hermaphroditic surf clams, *Spisula solidissima*. (A) Testicular (♂) and ovarian (♀) alveoli and duct containing parasites (tp); and (B) parasite tissues and spermatozoa in the clam collected on August 7, 1968. (C) Testicular (♂) and ovarian (♀) alveoli and duct containing parasites (tp); (D) parasite tissues and spermatozoa; (E) oogenic cells; and (F) spermatogenic cells in the clam collected on June 22, 1969. A scale of magnification is in the left hand corner of each photograph.

adults (Otto, personal communication). Coe and Turner (1938) found "no evidence of protandry or change of sex" in the species, but did find three hermaphrodites in over 1,000 examined from New Haven, Connecticut, and reported a prevalence value of less than 0.5% (Table 1); Shaw (1970) found one in 36 from Umpqua Bay, Oregon, a prevalence of 2.8%; and Porter (1974) found one in 1,785 from Skagit Bay, Washington, a prevalence of 0.00056%. Other investigators have examined many (ca. 5,600) soft-shell clam gonads without finding any hermaphrodites (Ropes and Stickney, 1965; Pfitzenmeyer, 1965; Shaw, 1962, 1965; Brousseau, 1978; Table 1). The prevalence of hermaphroditism from all these observations is 0.35%.

Although soft-shell clams are generally considered to be a gonochoristic species, Coe and Turner (1938) observed that "the differentiated young gonad shows some indications of bisexuality" and their figure 17 includes "ovocyte-like" cells in the spermary of a young clam. If, in fact, the potentialities for both sexes exist in the gonads of young soft-shell clams and extrinsic conditions cause hermaphroditism, then it can be theorized that the population sex ratio might also be affected. The sex ratios of gonochoristic species are generally thought to approximate equality and, thus, the observed frequency in

samples can be subjected to goodness of fit tests.

The highest per-sample prevalence (4-8%) of hermaphroditic soft-shell clams was reported by Otto (1973); a sex ratio of 1:0.82 males to females was noted in these samples. No significant differences ( $P>0.05$ ) in the sex ratios, however, were detected in any of the sets of samples. Thus, an imbalance in the sexuality of these clams was not observed.

The hermaphroditic surf clam found in 1968 and 1969 were from the environmentally stressed New York Bight area, which has and is being intensively studied to identify the ecological effects of waste disposal practices (Gross et al., 1976). Although the impact of these spoils on the surf clam resource in this region is not well understood, sublethal effects are suspected to have important impact on some or all life stages of marine animals, possibly influencing survival, normal growth, and other physiological processes related to disease and parasitism (Sindermann, 1976). High incidences of chromosome or mitotic irregularities have been found in developing mackerel eggs from the area (Longwell, 1976). Surf clams are non-migratory, sedentary, and infaunal creatures. They cannot avoid the impact of contaminants.

Environmental stress has occurred in the

TABLE 1. *Observations of hermaphroditism in the soft-shell clam, Mya arenaria.*

Location	No. clams examined	No. hermaphrodites	Reference
New Haven, Conn.	>1,000	3	Coe & Turner, 1938
Tred Avon R., Md.	1,063	0	Shaw, 1965
Patuxent R., Md.	> 700	0	Pfitzenmeyer, 1965
Maine to Mass.	1,400	0	Ropes & Stickney, 1965
Umpqua Bay, Oreg.	36	1	Shaw, 1970
Chesapeake Bay	1,311	10	Otto, 1973
Skagit Bay, Wash.	1,785	1	Porter, 1974
W. Gloucester, Mass.	2,480	0	Brousseau, 1978



area. Anoxic conditions off the New Jersey coast in 1976 resulted in the loss of a large portion (144,672 metric tons of meats and 61.5%) of the surf clam biomass (Ropes et al. 1979). Ogren and Chess (1969) observed mortalities of surf clams and other marine animals related to anoxia around wrecks and reefs off New Jersey in 1968.

Environmental stress affecting the survival of surf clams in the New York Bight might cause atagenesis and sex ratio imbalances. Data from observations on 2,307 gonadal tissues of surf clams were available from several sources: samples taken during 1962-1965 to study the

reproductive cycle of the clam in off-shore New Jersey waters (Ropes, 1968b); and from locations off Long Island, NY, to off Virginia. 42 samples taken during surveys in the spring and fall of 1965; 35 samples taken in 1968; and 9 samples taken in 1969 (Table 2). In general, the hypothesis of an equality in the sex ratio of surf clams can be accepted, based on the combined totals and chi-square test results of all but three 1969 samples. These latter, taken off Point Pleasant, NJ, are an exception, since the differences in sex were highly significant ( $X^2 = 10.36$ ;  $df = 2$ ;  $P > .01$ )--78.6% of the clams were females; 17.9% were males; and 3.6% her-

TABLE 2. The sex ratio of surf clams (*Spisula solidissima*)

Area	Year	Number of samples	Number of males	Number of females	Total	$\chi^2$
Long Island	1965Sp	4	17	22	39	0.6410
	1965Fa	5	27	18	45	1.8000
	1968	7	38	35	73	0.1233
	1969	1	4	6	10	0.4000
Total		17	86	81	167	0.1498
Pt. Pleasant, NJ	1962	8	74	98	172	3.3488
	1963	20	244	246	490	0.0082
	1964	20	240	244	484	0.0330
	1965	14	170	198	368	2.1304
	1965Sp	4	18	18	36	0.0000
	1965Fa	5	28	21	49	1.0000
	1968	14	58	73	132 <sup>1/</sup>	1.7121
	1969	3	5	22	28 <sup>1/</sup>	10.3571
Total		88	837	920	1759	3.9187
Cape May-Wildwood, NJ	1965Sp	6	18	30	48	3.0000
	1968	8	45	36	81	1.0000
	1969	4	26	14	40	3.6000
Total		18	89	80	169	0.4792
Delmarva Peninsula & Virginia	1965Sp	5	25	23	49 <sup>1/</sup>	0.0202
	1965Fa	13	46	48	94	0.4256
	1968	6	27	33	60	0.6000
	1969	1	6	3	9	1.0000
Total		25	104	107	212	0.0471
Grand Total		148	1116	1188	2307	2.2510

<sup>1/</sup> Includes a hermaphrodite in the total.

nephroditis. However, the sample size may have been too small to make the test statistically conclusive (Dixon and Massey, 1957). The prevalence of hermaphroditism in all of the samples was a low 0.13%; the sex ratio was 1:1.0645 males to females.

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## IN VITRO CULTURE OF PARASITIC FRESHWATER MUSSEL GLOCHIDIA

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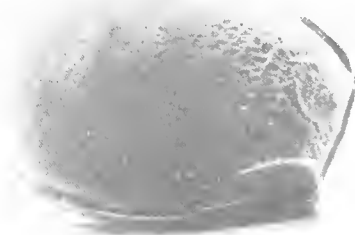
### ABSTRACT

*Ellis and Ellis (1926 and 1930) reported transformation of freshwater mussel glochidia in vitro culture. However, their methodology was never published. This report gives a new method for the in vitro culture of mussel glochidia to juveniles rather than by their natural fish host encystment. The medium consists of physiological salts, amino acids, glucose, vitamins, antibiotics, and a nonspecific component of fish blood plasma. The relative concentration of fish plasma required for optimum results was 33 percent. In vitro culture may prove very beneficial in reestablishing the populations of endangered mussels, management of species used by the pearl culture industry, and culturing of stocks for bioassays, genetic studies, or other uses.*

Application of in vitro culture for the purpose of sustaining endangered mussels of commercial importance is obvious, since usually an unknown fish host is required for larval development in nature. The female mussel has her eggs fertilized by sperm cells which are released into the water by a male mussel and travel into the female with water taken in during filter feeding. The fertilized eggs, contained in the female's gills, develop into simple glochidia, or larvae, consisting primarily of two shells, mantle cells, and one adductor muscle. The glochidia are released and encyst in a specific fish tissue, usually the gills. Development of glochidia into juveniles (transformation) in an artificial medium would help endangered mussels, since the fish host required for most of these species is unknown and would be difficult to determine. The fish host of some species may even be extirpated. Use of in vitro culture could sustain a species until its fish host could be found or the absence of a host availability determined. Even mussels with a known fish host could be reared for commercial or scientific purposes.

Freshwater mussels have been used commercially for manufacturing buttons and presently as nuclei for cultured marine pearls. They are

also currently being used for the culture of freshwater pearls in the United States. Overharvesting as a result of demand for shells has contributed significantly to the decline of freshwater mussel resources in the United States over the past three decades. Historically, over 500 of the more than 1000 world species of freshwater mussels occurred in the United



**811-211-200X LIGUMIA RECTA**

FIG. 1. Glochidial shell of the freshwater mussel *Ligumia recta* (length 260  $\mu$ m).

States. Many species are now thought to be extinct; others are listed as threatened or endangered by individual states or the United States Government.

Ellis and Ellis reported in 1926 that they had successfully obtained transformation of parasitic glochidia of freshwater mussels in physiological nutrient solutions. However, neither the composition of the media nor the process used was ever published. In addition, unlike the present study, Ellis and Ellis excised the glochidia they used from a known fish host, an action which undoubtedly contributed to their reported success.

Composition of our artificial medium include salts which are modified from the "unionid Ringers" solution proposed by Ellis et al. (1930) and are shown in Table 1. The essential modification of the solution includes the deletion of  $K_2HPO_4$  and the addition of 2.2 gm  $NaHCO_3$  per 1000 milliliters of solution. The  $NaHCO_3$  was required in order to regulate the pH with varying atmospheric  $CO_2$  concentrations.

TABLE 1. *Salts contained in stock artificial glochidial medium.*

Compound	Concentration (mg/L)
$CaCl_2$	1200
$MgCl_2 \cdot 6H_2O$	1000
$NaCl$	1530
$KCl$	99
$NaHCO_3$	2200

The amino acids in the artificial medium are the same as those used by Eagle (1959) for cell and tissue cultures with the exception of the addition of taurine and ornithine which are constituents of fish blood. The essential amino acids are shown in Table 2, the nonessential amino acids in Table 3.

The vitamins present in the complex artificial growth medium, the same as those used by Eagle (1959) for cell and tissue cultures, are shown below in Table 4. The antibiotics and antimycotic used in the artificial medium are listed in Table 5; other compounds are shown in Table 6.

Plasma was obtained from fish blood which

TABLE 2. *Essential amino acids contained in stock artificial glochidial medium.*

Compound	Concentration (mg/L)
L - arginine	105
L - cystine	24
L - histidine	31
L - isoleucine	52
L - leucine	52
L - lysine	58
L - methionine	15
L - phenylalanine	32
L - threonine	48
L - tryptophane	10
L - tyrosine	36
L - valine	46

TABLE 3. *Nonessential amino acids contained in stock artificial glochidial medium.*

Compound	Concentration (mg/L)
L - alanine	8.9
L - asparagine	13.2
L - aspartic acid	13.3
glycine	7.5
L - glutamic acid	14.7
L - proline	11.5
L - serine	10.5
taurine	31.0
L - ornithine	10.0

TABLE 4. *Vitamins contained in stock artificial glochidial medium.*

Compound	Concentration (mg/L)
choline chloride	1.0
folic acid	1.0
inositol	2.0
nicotinamide	1.0
calcium pantothenate	1.0
pyridoxal	1.0
riboflavin	0.1
thiamine	1.0

was removed from the fish by heart puncture with a sterile heparinized syringe (the syringe chamber was coated with a sodium heparin solu-

TABLE 5. The antibiotics and antimycotic contained in stock artificial glochidial medium.

Compound	Concentration
Antibiotics	
Carbenicillin	100 µg/ml
Gentamicin sulfate	100 µg/ml
Rifampin	100 µg/ml
Antimycotic	
Amphotericin B	5 µg/ml

TABLE 6. Other compounds contained in stock artificial glochidial medium.

Compound	Concentration (mg/L)
Glucose	1000.0
Phenol red (optional)	10.0

tion of 1000 U/ml) having an 18 gauge needle. The blood was centrifuged at 1000 rpm in a refrigerated centrifuge for 10 minutes followed by 3000 rpm for 10 minutes, decanted into sterile centrifuge tubes, and centrifuged for another 10 minutes. The plasma was removed by aspiration, then frozen and subsequently sterile filtered. The antibiotics and antimycotic were added to the plasma in the same concentration as shown in Table 5, at time of use.

Glochidia from gravid female mussels were obtained by utilizing sterile surgical instruments to remove the gills containing glochidia, then the gills were placed in sterile deionized water. The glochidia were excised from the gills by sectioning and then swirling the gills in the deionized water.

The glochidia were washed several times with deionized water by decanting or aspirating the water following swirling of the beaker contents. The healthy glochidia settled, allowing the removal of tissue debris, dead glochidia, bacteria, and protozoa. The glochidia were left in the last rinse water until they were removed with a Pasteur pipette and placed in the growth medium. A representative scanning electron photomicrograph of a glochidium of *Ligumia recta* (Lamarck, 1819) is shown in Figure 1.

Different components and concentrations of the growth medium were tested to determine which combination would stimulate and best

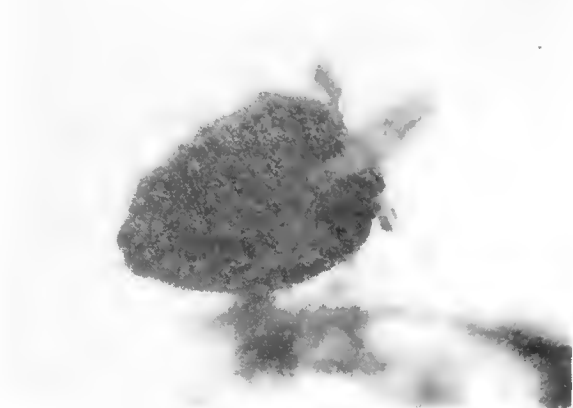


FIG. 2. Transformed juvenile of the freshwater mussel *Ligumia recta*, 39 days old, in lake water. Note the protruding ciliated foot.

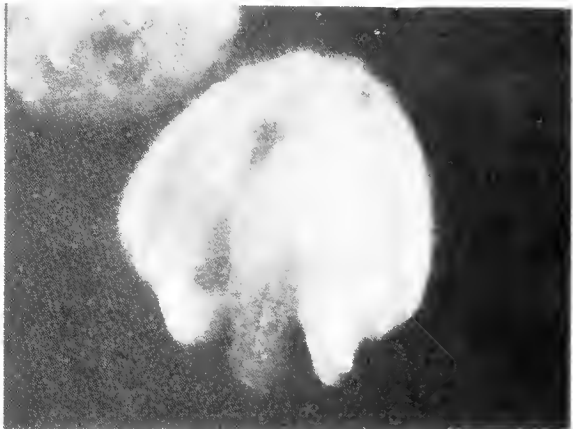


FIG. 3. Growth of juvenile *Ligumia recta*, 15 days in culture, 13 days in water (dark field), a total of 28 days. End view showing protruding foot in center.

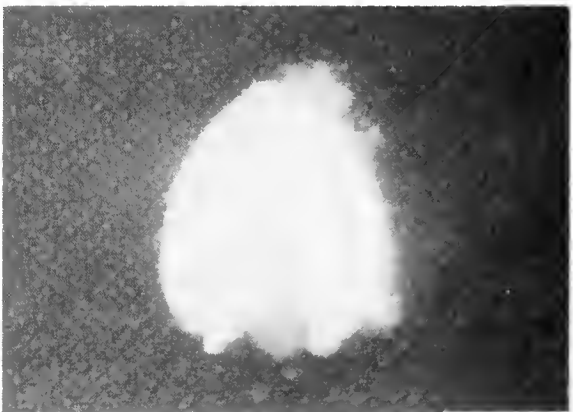


FIG. 4. Growth of juvenile *Lampsilis ovata*, 22 days culture, 9 days in lake water (dark field), a total of 31 days old.

support glochidial transformation. Numerical comparisons of different cultures were difficult to evaluate because the varying stages of development in, as well as the number of, glochidia. The presence of bacteria in initial cultures in 1981 further confounded the accuracy of numerical culture evaluations. Many cultures failed to yield fully transformed glochidia because of bacterial infections, even though most glochidia had good initial development prior to their contamination. Experiments in 1982 with the new antibiotics shown in Table 5 have been much more successful.

Only two different salt solutions, unionid Ringers (Table 1) and Earles' balanced salt solution (Earle, 1943), were compared in experiments. Glochidia transformed in both salts, even though the amino acids used in conjunction with each varied slightly. Because parasitic glochidia are surrounded by fish cells, and since Earles' is the salt solution most commonly used in fish cell culture medium (Wolf and Quimby, 1969), glochidial adaptation for life in Earles' salt concentrations as well as in unionid Ringers would be expected.

Different groups of amino acids were tested in cultures to get transformation, but elimination of nonessential, single, amino acids has not been attempted to date. In earlier experiments with the medium being 20 percent artificial, the amino acid content seemed less important, probably because the 80 percent plasma had the necessary concentrations of amino acids. The artificial growth medium was formulated to include all free amino acids which had been found in three species of catfish (*Ictalurus furcatus*, *I. punctatus*, and *Pygocentrus nattereri*) (Johnson, 1971). All of the amino acids which had been found in fish blood could also be found in equal or higher concentrations in Eagles' essential and nonessential amino acids if taurine and L-ornithine were added. The only amino acid found in Eagles' amino acid group which was not found in the catfish blood was L-tryptophan. Since Eagles' amino acids could be purchased premixed, this combination was used along with taurine and L-ornithine in the successful *in vitro* medium. Medium 199, which also has 21 amino acids (Morgan et al., 1950), was

sufficient for glochidial transformation. Medium 199 has the same 12 essential amino acids as Eagles' medium; however, medium 199 is lacking 4 of the 9 nonessential amino acids which had been used. This would indicate that these four (L-alanine, L-asparagine, L-ornithine, and taurine) were not necessary for glochidial development. Even though development occurred in both media, the development rate was faster in Eagles' amino acids with taurine and L-ornithine than in medium 199.

Fish blood plasma was found to be necessary to stimulate development in all mussel species tested. Other massive protein components, specifically fetal bovine serum, bovine serum, and lobster hemolymph, were tested and found unsuccessful. Although earlier tests indicated a positive correlation between percent transformation and percent fish blood plasma in the medium, 33-1/3 percent blood plasma was adopted in our standard medium as producing satisfactory yields at a more economical level.

Earlier cultures of *Legumia recta* were placed in unfiltered plasma which contained several blood cells. First observations seemed to indicate that development was enhanced by the presence of these cells. The glochidia were held in a matrix of cells and fibrin on the dish and developed rapidly. Subsequent media changes were made using filtered plasma to prevent a buildup of cells in the culture. Conversely, later cultures with *Fusconia ebena* (Lea, 1831) did not show any indication of enhancement by the presence of these cells. In fact, cultures with unfiltered plasma suffered a higher rate of contamination which resulted in a lower yield. More work is needed in this area, but the presence of the fish cells does not appear to be necessary for glochidial development.

The pH of the medium varied from ca. 7.3 to 8.1; however, the lower pH promoted best transformation in at least one species. Cultures of *Fusconia ebena* developed much better in a pH range of 7.3 to 7.4 rather than 7.8 to 8.0. For example, in eight different cultures of *F. ebena*, 16 of 26 culture dishes contained transformed juveniles after 18 days at a pH of ca. 7.3, whereas none of an identical set of 26 cultures were alive at 11 days when cultured at a pH of ca. 7.9.

Bacterial infection was present in cultures at both pH levels and was responsible for much of this loss; however, many of the higher pH cultures died even when bacterial action was minimal, while infections in the lower pH cultures did not result in death of the entire culture. The lower pH level appeared to either make it easier to control bacterial contamination or minimize the detrimental effects of the bacteria. Subsequent experiments have corroborated that a pH of 7.3 is optimum.

The use of antibiotics and their concentrations varied with the presence or absence of bacteria in the medium. Carbenicillin, usually added to yield 100 µg/ml, can be increased to as high as 500 µg/ml without apparent inhibition to the glochidial development. Gentamicin sulfate and Rifampin can also be increased from 100 µg/ml to 500 µg/ml safely, and the antimycotic, Amphoterin B (Fungizone) from 5 to 25 µg/ml. These antibiotics and antimycotic, along with rinsing and changing infected glochidia to new media and dishes, usually would control contamination successfully. Older glochidia could withstand infection much longer than younger glochidia.

The medium was kept at 23°C but cultures were successful, to a lesser extent, even at 28°C. Higher temperature did reduce the yield, as shown by the comparison of glochidia of *Ligumia recta* which developed in 23°C and 28°C. Using six culture dishes grown in 60 percent plasma, three grown in 23°C had an average yield of advanced glochidial development equal to 48.8 percent ( $S\bar{x}=8.7$ ), while those grown at 28°C averaged 18.8 percent ( $S\bar{x}=3.3$ ). A transformed glochidium of *Ligumia recta* is shown in Figure 2.

During the spawning season of 1982, these variables have been refined to a greater degree, resulting in successful mass culturing of glochidia (some cultures averaging as high as 80 percent transformation). These successes will provide opportunity for conservation of many mussel species including endangered species, and the management of others. Efficacy of the process to date includes transformation of glochidia of six genera and species representing two subfamilies of Unionidae, the Unioninae and Lampsilinae.

A growth stage of a juvenile *Ligumia recta* is shown in Figure 3 and that of a *Lampsilis orata* in Figure 4.

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### Recent Deaths

We regret to announce the death of our dear friend, Katherine Van Winkle Palmer, former Director of the Paleontological Research Institution, of Sept. 12, 1982, at the age of 87. Contributions to her memorial fund for P.R.I. may be sent to Dr. Raymond Van Houtte, Tompkins County Trust Co., Ithaca, NY 14850. An obituary is in preparation.

### Meeting

The Eighth International Malacological Congress, sponsored by the Unitas Malacologica, will be held in Budapest, Hungary, in 1983, from August 29 - September 3. Further information may be obtained by writing Dr. László Pintér, Natural History Museum, Baross u. 13, H-1088 Budapest, Hungary.

TEMPORAL SPACING IN THE ACTIVITY PATTERNS OF  
THREE HAWAIIAN SHALLOW-WATER OCTOPODS

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## ABSTRACT

*Three species of Hawaiian octopods show distinct locomotor activity rhythms in the laboratory and in the field. The periods of peak activity are species-specific even in isolation. This temporal spacing and differences in preferred microhabitats during periods of inactivity may limit interspecific competition for food and home sites and reduce the incidence of predation. Inactive Octopus ornatus superficially behave like vertebrates in sleep.*

Animals occupying similar niches in the same geographical area may reduce competition by a variety of spacing mechanisms. Three species of shallow-water octopods can be collected on the same fringing reef flats off the south shore of Oahu, Hawaii, throughout the year. Data are presented indicating that these three species show temporal spacing in locomotor activity patterns. Observations in the field and in aquaria also suggest utilization of different microhabitats on the reef flat for use as refuges during periods of inactivity.

## Methods

Animals were collected by netting during low tides on shallow reef flats off the south shore of Oahu, Hawaii. *O. cyanea* Gray was collected before dusk and transported to the Hawaii Institute of Marine Biology, Kaneohe Bay, Oahu. Specimens of *O. ornatus* Gould and the "crescent octopus," a small undescribed Hawaiian octopod (Houck, 1977; reference specimens: Department of Invertebrate Zoology, Santa Barbara Museum of Natural History) were collected at night and maintained at the Bekesy Laboratory of Neurobiology, University of Hawaii.

Locomotor activity rhythms of four *O. ornatus* and twelve crescent otopuses were monitored in isolation under controlled laboratory conditions for periods of one to six months per

animal. Locomotor activity rhythms of each animal were recorded under a variety of light-dark regimes. Only typical activity patterns under light-dark conditions similar to timing of field illumination are reported here. An ultrasonic activity monitor allowed continuous recording of all movement of an animal within a light-tight aquarium. Data were read by a DEC PDP 11/10 computer and stored on cassette tape for later analysis. A complete description of the monitoring system is provided elsewhere (Akaka and Houck, 1980). The animal within the aquarium was exposed to an artificial light illumination with light intensity of 7.5 watts/m<sup>2</sup>, an average value at 0630 hours in a typical octopus habitat (Franzisket, 1969). Hourly activity values were computed as a percentage of the mean hourly activity for a monitoring run.

The larger size of specimens of *O. cyanea* did not permit use of the ultrasonic monitoring system since the animals were too large for the aquaria. Activity of *O. cyanea* was recorded by providing the animal with a single cinderblock "refuge" within a 6 foot trough functioning as part of an open sea water system at the Hawaii Institute of Marine Biology. The cinderblock "refuge" was equipped with a trap door bottom that was activated when the animal retreated into the depression of the block. A multichannel event recorder documented time spent inactive within the refuge. Hourly activity values were



calculated as a percentage of the mean hourly activity, with time spent out of the refuge considered activity. Specimens of *O. cyanea* were exposed to a diffused natural light regime.

### Results

*O. cyanea* is reported to be active during the day and inactive at night (Van Heukelem, 1966; Yarnall, 1969) while *O. ornatus* is considered by local fisherman to be night active. No previous data on locomotor activity or behavior of the crescent octopus have been published. The locomotor activity rhythms demonstrated in this

study were species-specific in pattern, and peak activity of each species was distinct from peak activity of the other two.

In this as in previously published studies, *O. cyanea* showed diurnal activity. Maximum locomotor activity, as measured by time spent out of the prepared "refuge", occurred just after dawn at 7 am (activity from 0600 to 0700 hours) and in a broad peak between 1300 and 1800 hours. Activity was maintained throughout daylight hours. Van Heukelem (1966) and Yarnall (1969) reported *O. cyanea* to be diurnally active, with crepuscular peaks in activity. This diurnal pat-

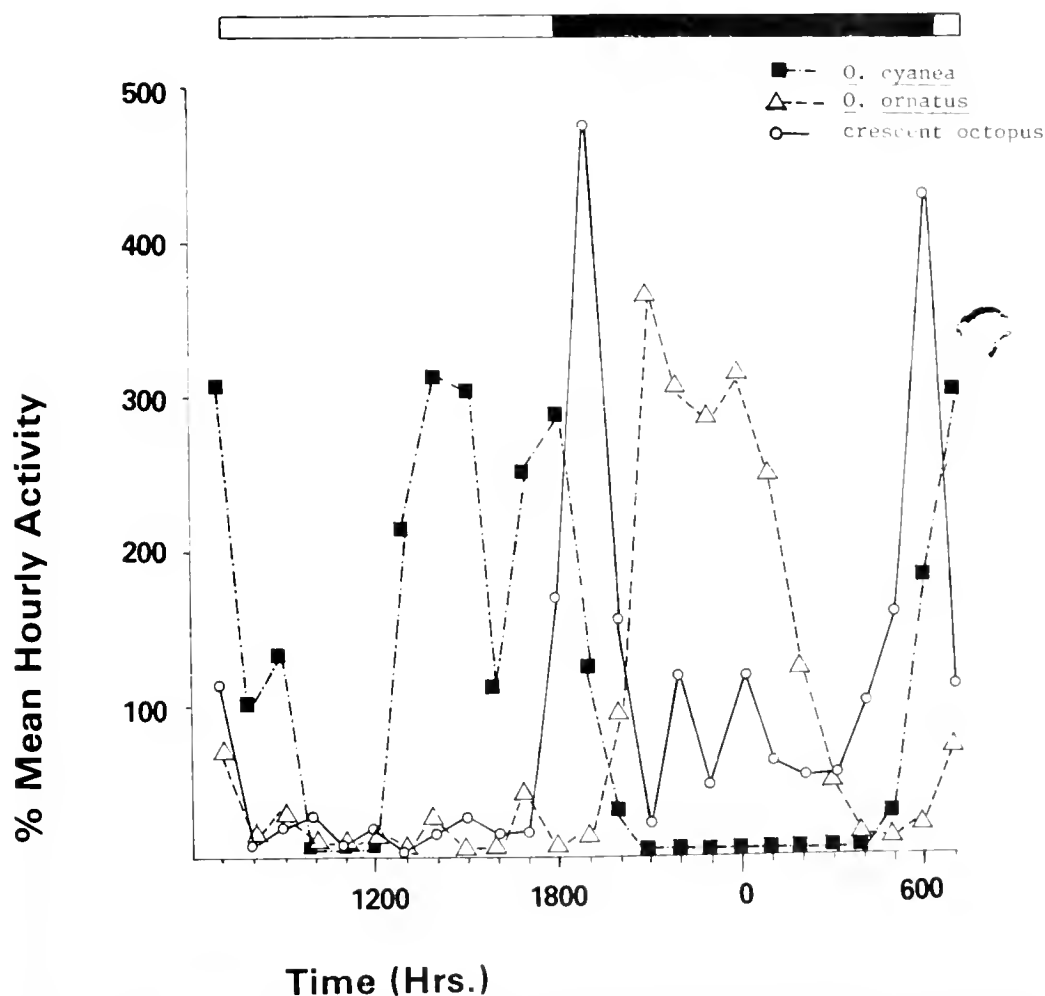


FIG. 1. Locomotor activity patterns for three species of shallow water Hawaiian octopods. *Octopus ornatus* record is based on 64 continuous hourly values, *O. cyanea* record is based on 24 continuous hourly values, and the "crescent octopus" record is based on 91 continuous hourly values.

tern is confirmed in the record of locomotor activity seen in Fig. 1.

*O. ornatus* demonstrated a nocturnal pattern of overall activity in the aquarium as recorded by the ultrasonic monitoring system. With a light regime of twelve hours of light and twelve hours of darkness, peak activity occurred in the middle of the lights off period. A dark period from 6 pm (1800 hours) to 6 am corresponded to natural conditions on the reefs in Hawaii (US Department of Commerce, 1944); under this light regime, *O. ornatus* was maximally active from 2100 hours to 0200 hours.

The crescent octopus also demonstrated nocturnal activity in the aquarium as recorded by the ultrasonic monitor, but maximum activity of the crescent octopus occurred during those hours of darkness when *O. ornatus* showed reduced locomotor activity. Under the light regime in which the lights off period extended from 1800 hours to 0600 hours, the crescent octopus was most active in the hour immediately after artificial dusk (1800 to 1900 hours) and immediately before dawn (0500 to 0600 hours).

Periods of inactivity in all three species were characterized by an almost complete lack of movement, other than regular mantle respiratory movements. The ultrasonic monitor was especially useful for examination of these periods of inactivity, since it recorded even small twitching of a single arm. Numerous observations were made of *O. ornatus* in the aquarium during the inactive period. During these periods, the octopus was found at the bottom of the tank with its eyelids closed, its arm wrapped about its head and mantle, a white translucent color to its skin that was quite distinct from the bright red and white banded appearance of an active animal of this species. Respiratory movements were regular, and sensory perception was sufficiently suppressed for the author to be able to move a small net about the tank vigorously without the animal responding in any way. When the animal was touched, it reacted violently with what could be called a startled reaction. It opened the eyelids, rapidly spread its arms and frequently expelled water through its funnel at the source of the intrusion. This behavior super-

periods of inactivity. Other marine invertebrates show periods of heightened and reduced locomotor activity (DeCoursey, 1976) but no other marine invertebrate has been reported to exhibit such pronounced sleeplike behavior.

The patterns of locomotor activity demonstrated in aquaria by the three species were reflected in observations in the field. When diving on the reefs of Oahu during the day, *O. cyanea* was the only species commonly sited. At night it was unusual to find this species on the reef. Yarnall (1969) and Van Heukelem (1966) report that *O. cyanea* retreats to its den at night, often blocking the entrance with stones. *O. ornatus* was never observed by the author on the reef during the day, and the crescent octopus was rarely seen. *O. ornatus* was most easily collected after 9 pm (2100 hours); when low tides occurred in the middle the night, *O. ornatus* was frequently seen fully exposed and moving freely across the reef flat or on sand and gravel substrates. The crescent octopus was routinely collected after dusk in shallow tide pools where the animals positioned themselves under rock ledges at or near the air-water interface.

Although all three species of octopods can be found within 100 feet of each other on a shallow reef flat, there are differences in the substrates of the microenvironments favored by each species. *O. ornatus* cannot be observed on the reef during inactive periods. When provided with a gravel or coral substrate in an aquarium, *O. ornatus* will burrow under the gravel and disappear from sight during the lights on period. The crescent octopus, as mentioned above, frequents the undersurface of ledges at the air-water interface in tidepools. In an aquarium, the crescent octopus assumes a position at this interface, often with several arms extended over its head, the suckers resting at the water surface. *O. cyanea* has been located in sites under large coral boulders or holes at the base of concrete walls (Van Heukelem, 1966; Yarnall, 1969). Yarnall reports use of the same "refuge" by several *O. cyanea* in succession. In an aquarium, *O. cyanea* will readily inhabit a concrete block or a length of PVC tubing.

## DISCUSSION

Octopods demonstrate a variety of locomotor activity rhythms in the aquarium and in the field (Woods, 1965; Van Heukelem, 1966, 1976; Altman, 1967; Yarnall, 1969; Kayes, 1974; Houck, 1977). The three species of Hawaiian octopods in this study show species-specific temporal spacing in locomotor activity rhythms. This spacing may influence the diet of each species. In the laboratory, all three species will readily accept much the same variety of grapsid crabs and shrimp species as food. Crustaceans show locomotor activity patterns of their own, often entrained by photoperiod and tidal rhythms (DeCoursey, 1976). In the field, hunting activity by an octopus at a specific time of day may restrict the types of crustaceans eaten, reducing interspecific competition for food.

The distinct locomotor activity rhythms of the three species of octopods, coupled with the differences in habitat and substrate preference, minimize interspecific contact in the field. Competition for food may not be the only factor impacted. Octopods are predators on other members of the genus (Van Heukelem, 1976); larger animals will readily feed upon small individuals. The three species of this study vary dramatically in size. *O. cyanea* is the largest, with maximum weight over 5 kilograms. *O. ornatus* has a middle size range, with mature individuals of 500 grams common. The crescent octopus is the smallest species. Maximum size of any individual collected by the author was 90 grams. The vast size difference may encourage the smaller species, especially the crescent octopus, to limit activity to periods when contact with the larger individuals of other species is unlikely. It should be noted, however, that activity rhythms were recorded and maintained in the laboratory in isolation, so visual observation of individuals of the same or other species is not required for demonstration of locomotor patterns. Boyle (1980) indicates that a larger octopus may take food forcefully from a smaller octopus, so temporal spacing may be especially beneficial to smaller species.

Competition for home sites in the aquarium has been documented in *Octopus vulgaris* Cuvier (Boyle, 1980). On the reef flats on the south

shore of Oahu, tide pools, coral heads and coral rubble are found near each other. By inhabiting one of these microhabitats over others, the three species of Hawaiian octopods in this study may minimize interspecific contact and reduce competition for home sites. When this habitat selection is coupled with the temporal spacing evident in activity periods, contact between species may be effectively reduced.

Thus, *Octopus cyanea*, *O. ornatus* and the "crescent octopus" show distinct species-specific patterns of locomotor activity in the laboratory under light regimes similar to those in the field. The three species are active on the same reefs on the south shore of Oahu at different times of the day. These times correspond to the periods of maximum activity recorded in the laboratory.

## ACKNOWLEDGMENTS

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## REDISCOVERY OF THE MARGINELLID GASTROPOD *PERSICULA TESSELLATA* (LAMARCK, 1822) ON THE PACIFIC COAST OF PANAMA

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### ABSTRACT

*Specimens of Persicula tessellata (Lamarck, 1822), a species originally described from an unknown province, are here recorded from the Pacific coast of Panama and are compared with Persicula accola (Roth and Coan, 1968) from the same area. The identity of Persicula porcellana (Gmelin, 1791), a Caribbean species that has been confused with P. tessellata, is reevaluated.*

Live-collected specimens of a *Persicula* from Pacific Panamic waters submitted to the American Museum of Natural History by James Ernest agree well with the holotype of *Marginella tessellata* Lamarck, 1822, described from an unknown locality. These specimens permit a reevaluation of the synonymy of *Marginella tessellata* with *Voluta porcellana* Gmelin, 1791, first advanced by Reeve (1846) and perpetuated in the west American literature (Keen, 1958; Coan and Roth, 1966; Roth and Coan, 1968). *Persicula tessellata* (Lamarck) is here removed from the synonymy of *P. porcellana* (Gmelin, 1791) and is recognized as an inhabitant of tropical west American waters. The Pacific Panamic *Persicula accola* Roth and Coan, 1968 is compared with Lamarck's *P. tessellata*, and the identity of Gmelin's *P. porcellana* from the tropical western Atlantic is reconsidered.

CAS = California Academy of Sciences  
MCZ = Museum of Comparative Zoology,  
Harvard University  
USNM = National Museum of Natural History,  
Smithsonian Institution

*Family* Marginellidae Fleming, 1828

*Genus* ***Persicula*** Schumacher, 1817

Type species by monotypy: *Persicula variabilis* Schumacher, 1817 (= *Voluta persicula* Linnaeus, 1758). Recent, west Africa. Medium-sized to small marginellids with flat spire usually concealed by callus; aperture narrow throughout its length; anterior end strongly notched; most species strikingly marked or colored. Eocene to Recent, Old and New World tropics.

***Persicula tessellata* (Lamarck, 1822)**

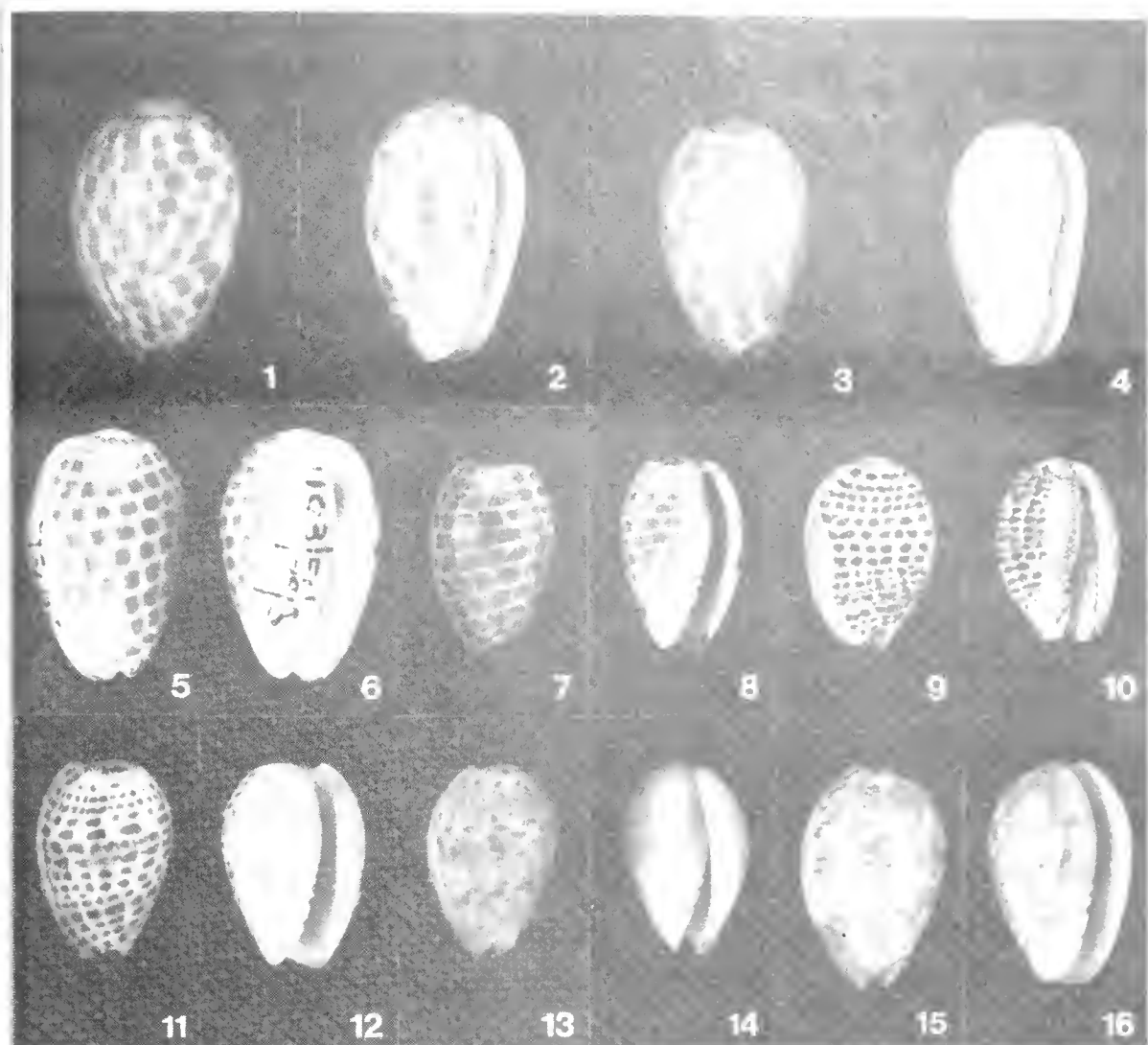
(Figs. 1-6)

*Marginella tessellata* Lamarck, 1822:361-362. Kiener, 1834:24, pl. 5, fig. 20.

*Marginella porcellana* (Gmelin), Reeve, 1864:pl. 13, figs. 53a, 53b.

### Institutional Abbreviations

AMNH = American Museum of Natural History  
ANSP = Academy of Natural Sciences of  
Philadelphia



FIGS. 1-6. *Persicula tessellata* (Lamarck, 1822). 1-4, specimens from Los Zurracos, Isla Chiriquí, Panama, ex Ernest Collection; 1, 2, (AMNH 208760), 3, 4, (AMNH 208761); • 2. 5, 6, holotype of *Marginella tessellata*, Lamarck Collection, Mus. Hist. Nat. Geneva, courtesy of Dr. E. Boidin; • 2.1. 7, 8, *Persicula accola* Roth and Coan (1968), Isla Perida, Panama, (AMNH 202770); • 2. 9-16, *Persicula porcellana* (Gmelin, 1791). 9, 10, reproduction of Chemnitz (1788) figures 1419 and 1420, Spengler collection; • 1. 11, 12, beach specimen from "Venezuela" (AMNH 49673, ex Constable Collection, received in 1901); • 2. 13, 14, Specimen from Puerto La Cruz, Venezuela (AMNH 203045); • 2. 15, 16, specimen from "St. Martha," Colombia in the Redfield Collection (ANSP 29116), labeled typological lot of *Marginella obesa* Redfield; • 2.

*Persicula porcellana* (Gmelin), Jousseaume, 1875:260. Keen, 1958:436, fig. 680. Coan and Roth, 1966:282-283 (in part), pl. 48, figs. 14, 15 (non figs. 16, 17, which = *Persicula accola* Roth and Coan, 1968). Roth and Coan, 1968:63, pl. 7, figs. 5, 6.

Non *Voluta porcellana* Gmelin, 1791:3449

Non *Marginella tessellata* Wood, 1828:42, pl. 3, fig. 31 [= *P. accola* Roth and Coan, 1968].

*Original description* — "24. Marginelle parquettée. *Marginella tessellata*. *M. testâ* obovatâ, apice retusâ, albidâ, punctis raris quadratis transversim seriatis tessellatâ; seriis cæteris; columellâ plicis præcipuis quinâ instructâ; supra aliis duobus seu tribus minimis; labro intus crenulato. An *voluta porcellana*? Chemn.

Conch. 10, t. 150, f. 1419, 1420, Gmel. p. 3449, no. 139." (Lamarck, 1822, p. 361).

*Type locality* – Unknown. Here designated, off Isla Cebaco, west Panama.

*Supplementary description* – The following description is based on seven specimens dredged in about 30 meters at Los Zurrónes, Isla Cebaco, Panama (7°10'10"N, 81°30'10"W) by James Ernest, 1982 (6 specimens, AMNH 208761; 1 specimen CAS 032387). Shell large for the genus, solid, ovate, diameter 0.61–0.67 times length; narrower anteriorly, greatest width at 60–64 percent of distance from anterior end; surface polished, unsculptured except for a few raised incremental lines. Color white with 9–11 spiral rows of grayish brown, subrectangular spots covering 60–80 percent of shell surface; most posterior row just below suture; most anterior row running along margin of anterior canal; spots irregularly spaced, not tending to align longitudinally, mostly wider than intervening spaces in a row; spiral rows added by fission of an existing row; incompletely split spots usually present. Spots well defined or slightly blurred (particularly on trailing edge) by overlying clear to translucent whitish callus. Spire covered by a flat or slightly projecting apical pad of white callus, circled by a ring of more or less fused reddish brown blotches; spacing of these blotches independent of pattern on body whorl. Outer lip strongly thickened by callus, not extending beyond apex, white, tinged along outer margin with reddish brown, finely denticulate on apertural edge, lirate within. Aperture narrow, almost even but slightly wider anteriorly, white inside, with acute posterior sulcus and deep, narrow, oblique anterior canal. Canal set off from body whorl by raised fasciolar flange; columellar side produced dorsally into a rounded spur, ticked posteriorly with reddish brown. Parietal wall moderately convex, shallowly excavated anterior to center; with thick white callus along its length, merging posteriorly with apical callus; left edge of callus a raised rim paralleling aperture. Columella with 8 folds including one at base of columella, decreasing in strength posteriorly; posterior fold sometimes barely perceptible; second fold from anterior end large, bifid.

*Dimensions of the seven specimens examined* – Largest specimen: length 18.4 mm, diameter 12.3 mm; smallest specimen: length 16.1 mm, diameter 10.6 mm; average for length: 17.5 mm; average for diameter: 11.1 mm.

## DISCUSSION

Comparison of the seven specimens from James Ernest with the holotype of *Persicula tessellata* (Figures 5, 6) leaves little doubt that they are conspecific. The holotype is 16.5 mm in length and 10 mm in diameter. It has 9 subequal rows of spots on the back of the body whorl; fission increases these to 12 by the last quarter of the whorl. The apical callus pad projects slightly. Interspaces in a row of spots are somewhat variable, particularly around the middle of the whorl. The thick parietal callus pad and shallow excavation of the parietal wall are exactly like those of the Ernest specimens (Figures 1–4).

The holotype is a slightly worn specimen. Its pattern is warm brownish orange. The superficial wash of milky callus that covers the shell in many *Persicula* species (e.g. *P. bandera* Coan and Roth, 1966; *P. hilli* (Smith, 1950); *P. accola* Roth and Coan, 1968; and the present species) imparts a grayish cast to the dark patterning underneath. When this layer is removed by erosion, the remaining pattern shows as a warm brownish red or orange, as in the holotype of *P. tessellata*. In the Ernest specimens, the difference in hue between the body-whorl pattern and the brown tinting on spire, outer lip, and canal is probably not the product of separate pigments, but the result of the body-whorl patterns being seen through the translucent wash of callus.

The Ernest specimens of *P. tessellata* differ in several ways from *Persicula accola* Roth and Coan (1968, pl. 7, figs. 7, 8). *P. accola* is smaller (range of 20 adult specimens examined: length 11.2–14.6 mm, diameter 7.0–9.1 mm). The rows of brown spots cover about 90 percent of the shell surface, the interspaces between them being narrow and uniform (Figures 7, 8); as in *P. tessellata*, the basic number of rows seems to be nine, with higher numbers always the result of fission of one or more rows. The spire is flat to very low, not projecting as in some *P. tessellata*,

and the apical callus is ringed by a dense, solid brown band or else (less commonly) entirely brown. The brown ticking on the anterior fasciolar flange is darker and more extensive than on *P. tessellata*; the brown patch on the outer margin of the thickened outer lip darker, longer, and more distinct. Most *P. accola* have seven columellar folds; occasionally a faint eighth fold is perceptible posteriorly. Specimens with five and six columellar folds occur.

All known occurrences of *Persicula accola* are on the Pacific coast of Panama between Punta Burica (8°02'N, 82°52'W) and Punta Mariato (7°12'N, 80°53'W), intertidally (Coan and Roth in Keen, 1971) to nine meters (AMNH 202770, AMNH 208759). Isla Cebaco, the source of the *P. tessellata* specimens, is also in this area. James Ernest (*in litt.* to Emerson, 18 May 1982) reports that *P. accola* is collected intertidally in sand mixed with mud, while *P. tessellata* is found in "deeper water [to about 30 meters] and white sand, with very clear water."

Gmelin (1791) described *Voluta porcellana* with reference to two figures in Chemnitz (1788) (Figures 9, 10) depicting a broadly ovate *Persicula* with 16 rows of small, irregularly shaped spots. The locality was cited as Indian Ocean, undoubtedly speculative since Gmelin probably had no firsthand knowledge of the source of the Chemnitz specimen. No occurrence of any *Persicula* resembling *P. porcellana* in the Indian Ocean has been confirmed in the many intervening years. (Nevertheless, a few poorly grounded citations in the later literature still place *P. porcellana* in the Indian Ocean; cf. Dodge's [1955, p. 85-86] speculative remarks.)

In describing *Marginella tessellata*, Lamarck (1822, p. 361-362) cited the same figure in Chemnitz with an interrogation mark, then went on to comment, about the specimen in his own collection ("Mon cab."), "Ses points ne sont pas sagittés comme dans le figure citée de Chemnitz, mais carrés." Most later authors, beginning with Reeve (1864) have interpreted Lamarck's species and Gmelin's as synonymous, perhaps mainly because both authors cited the same Chemnitz figure. Dodge (1955, p. 86) interpreted Lamarck's comment about the shape of the spots as a criticism of the fidelity of Chem-

nitz's illustration. It can equally well be seen as a statement of contrast between the Chemnitz specimen and Lamarck's own, which we accept as the holotypic specimen (Figures 5, 6).

Kiener (1834, pl. 5, fig. 20) illustrated as *Marginella tessellata* a specimen with eleven rows of subrectangular, brownish orange spots and a moderately projecting apical callus. At 26.5 mm in length, the figure is certainly enlarged; but with the allowance for a little bit of artistic license, it could practically be Lamarck's holotype.

Under the name *Marginella tessellata*, Sowerby (1846) illustrated three different specimens. His figure 195 is evidently *Persicula chrysomelina* (Redfield, 1848). Figure 194 shows the dorsal view of a *Persicula* 11.1 mm in length with nine spiral rows of variously sagittate, subrectangular and irregular spots. Figures 196 and 197 show dorsal and ventral views of a similar *Persicula* 14.8 mm in length with 13 rows of irregular to sagittate spots and a maculated outer lip. Sowerby's (1846, p. 395) description of the species characterizes the columella as white, swollen in the middle, and elevated into a swollen varix anteriorly. Sowerby was also the first to associate a locality with the name *M. tessellata*, stating that it was a common species from Venezuela.

The lack of precision in the Sowerby illustrations makes them somewhat difficult to interpret. However, the characters of maculation on the outer lip (visible in ventral view) and a tumid parietal callus rising to a ridge or varix anterior to the middle are strongly suggestive of an Atlantic species variously identified in museum collections as *Persicula obesa* (Redfield, 1846) and *P. porcellana* (Gmelin, 1791). Most of these specimens are from older collections and the localities are indefinite: Venezuela (AMNH 49643, ex James Arnold Constable collection; CAS 030298, ex Ruth Coats collection), Honduras (USNM 19617), "West Indies" (MCZ 265502). They have 14-16 spiral rows of spots. The spots are usually punctate, sagittate, or dash-shaped rather than rectangular; there is typically a zone of larger spots over the broadest part of the body whorl, and another, less pronounced, about one-fourth of the distance posterior to the

anterior end. The apical callus is flat or slightly projecting and strongly tinged with brown. The callus thickening of the outer lip is whitish, often with brown dashes echoing the color pattern of the body whorl. None of these specimens show the longitudinal brown patch of *P. tessellata* and *P. accola*. Authenticated modern records of this species in the western Atlantic are: Puerto La Cruz, Anzoategui, Venezuela, three specimens (AMNH 203045, ex F. J. Fernandez H. collection, 1976) (Figures 13, 14), Tobago, West Indies, two specimens (AMNH 141495, ex Mrs. Stuart Brown collection, 1967). Rios (1970, 1975) records this species (as *P. obesa*) from Brazil, but the cited specimens are actually from Venezuela (*teste* Rios, 1982).

The holotype of *Voluta porcellana* Gmelin, formerly in the Lorenz Spengler (1720–1807) collection of the University of Copenhagen, is lost (Coan and Roth, 1966). The Chemnitz drawings (cf. Figures 9, 10 with 11, 12) cited by Gmelin for his species agree more closely with the Caribbean species than with the Pacific *Persicula tessellata*. *Voluta porcellana* is the oldest name for the Caribbean species, with *Voluta albida* Bosc, 1801 (cites Chemn. figs. 1419 and 1420) and *Marginella obesa* Redfield, 1846 (not Sowerby, 1846) both junior synonyms. Redfield's taxon was based on specimens provided by W. W. Whitney from the "Caribbean Sea at Carthage, SA" [Colombia] that were deposited in the "Cabinet of the Lyceum" [of Natural History, New York City]. The collection of the Lyceum was destroyed by a fire in 1866, (Fairchild, 1887). There are, however, four specimens (ANSP 29116) from the collection of John H. Redfield (1815–1895) labeled as "types". None of these specimens match the measurements or figures cited in the original description (Redfield, 1846, p. 164, 165, pl. 10, figs. 5a, b). Furthermore, the locality for this lot is given as "St. Martha, S.A." [= Santa Marta, Colombia]. Although this may not represent the type lot, the specimens agree well with Redfield's description and illustration (see figures 15, 16). Three topotypical specimens of this taxon (ANSP 29386) are in the Robert Swift collection (1796–1872). *Marginella similis* Sowerby, 1846, from "Brazil", is a possible additional junior synonym

of *P. porcellana*. Redfield (1848) and others have referred Sowerby's taxon to the synonymy of *Marginella obesa* Redfield, but we have not examined the types of *M. similis*, which we presume are in the British Museum (Natural History).

Coan and Roth (1966) designated the holotype (which they called a lectotype) of *Marginella tessellata* to be a neotype for *Voluta porcellana*. Their aim was to cement the synonymy, generally accepted up to that time, of *M. tessellata* and *V. porcellana*. In light of the foregoing demonstration that *Persicula tessellata* is a Pacific species, and *Persicula porcellana* is a consistently differing Atlantic species, the Coan and Roth neotype designation fails to meet the provisions of ICZN Article 75 (c) (4), which states that to be validly designated a neotype must be published with "evidence that the neotype is consistent with what is known of the original type-material, from its description and from other sources." Coan and Roth (1966, p. 283) actually commented that the Chemnitz figures differed in pattern and proportions from any "*P. porcellana*" that they had examined at the time. We suggest that the neotype designation is invalid.

Coan and Roth (1966) first regarded *Persicula porcellana* as an eastern Pacific species and illustrated (1966, figs. 16–17) a specimen from Isla Coiba, Panama, under that name. Later, the same authors (Roth and Coan, 1968) distinguished *P. accola* as an eastern Pacific species (including the specimen they had figured in 1966), and allocated *P. porcellana* to the western Atlantic, stating that they had examined "from the Caribbean, specimens that look like Lamarck's type [i.e., of *P. tessellata*] and still others which closely resemble the original Chemnitz figures" (Roth and Coan, 1968, p. 63). Such specimens include MCZ 265501 (no locality; four *P. porcellana* and four *P. accola*), USNM 90175 ("Venezuela," ex Wesleyan University collection; two, probably *P. accola*), and USNM 413838 ("Brazil," ex Ford collection; one *P. accola*). It seems most probable that, with the exception of the four true *P. porcellana* in MCZ 265501, these all represent misallocations of eastern Pacific shells.



In summary, *Persicula tessellata* (Lamarek, 1822) and *Persicula accola* Roth and Coan, 1968, are similar eastern Pacific species occurring in the same part of western Panama. *Persicula porcellana* (Gmelin, 1791) is the valid name for a Caribbean species with more rows of finer spots; *Marginella obesa* Redfield, 1846, is synonymous.

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